This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

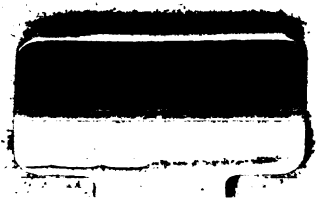
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

THN
P75

Library
of the
University of Wisconsin



STEAM INJECTORS:

THEIR THEORY

AND

USE.

UNIVERSITY OF WISCONSIN
No. 189
ENGINEERING LIBRARY.

TRANSLATED FROM THE FRENCH OF

M. LEON POCHET.

NEW YORK:
D. VAN NOSTRAND, PUBLISHER,
23 MURRAY AND 27 WARREN STREET.
1877.

16306

695 2 812

PREFACE.

The following brief treatise was translated without abridgement from *Nouvelle Mecanique Industrielle:* M. LEON POCHET. It first appeared in its present form in *Van Nostrand's Magazine* for March and April, 1877.

The literature bearing on the subject of the Injector is not abundant, and to many engineers the philosophy of the action of the apparatus is obscure. In view of the fact that uses for the Injector have been devised other than the feeding of boilers, is judged to be a sufficient reason for the preparation of this little work.

STEAM INJECTORS.

GENERAL THEORY OF STEAM INJECTORS.

It is some years since M. Giffard introduced the injector apparatus which bears his name and which filled the scientific world with profound astonishment.

This ingenious apparatus, in which a jet of steam heading out of a boiler enters into the same boiler bringing with it a quantity of additional water, seems to proceed in accordance with a philosophical law contradictory to the ordinary laws of physics. It was in appearance a sort of perpetual motion. If the mechanical properties of heat had been better known, nothing would have appeared more simple.

M. Reech, published, in 1858, (in the memorial du Genie Maritime), a theory

founded upon laws of the old philosophy, which gives a good account of the functions of the Giffard injector.

The new theory which we proceed to give—of the Giffard injector in particular, and of steam injectors in general—rests upon the mechanical theory of heat. It seems the more important inasmuch as injectors are now applied to such a great variety of purposes.

We will describe first the action of an injector. A tube terminating in a conical pipe A, Fig. 1 discharges a jet of steam which comes from the boiler. This tube opens into a chamber B B which communicates with a reservoir of cold water RR by a vertical tube CC. It is this water which is introduced into the boiler.

Under the action of the jet of steam the air in the chamber B is rarefied and the rarefaction results in the atmospheric pressure raising the water of the reservoir in the tube C. As soon as the cold water comes in contact with the steam in the chamber B a portion of the steam

is condensed and the apparatus is so regulated that this condensation is complete. Then we have, merely, a jet of liquid to pass on through the contracted

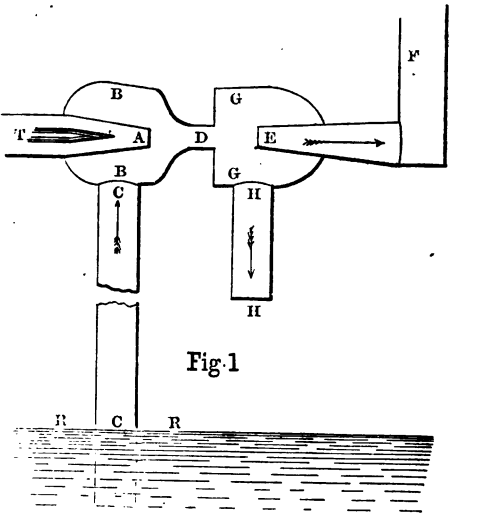


Fig. 1

section D and be introduced into the conical, diverging tube which communicates with the boiler. The tube EE is nothing more than a Venturi tube.

In such a tube, water introduced with

a certain velocity V would be able to overcome the pressure due to the height $\frac{V^2}{2g}$, provided that the liquid column be uninterrupted and the widening be progressive; or if we call ω the section of the tube at its origin, and ω' the section of the same tube at its entrance into the boiler, H the height of water corresponding to the effective pressure of the boiler, that is to say its absolute pressure diminished by one atmosphere, we shall have

$$\frac{V}{2g}\left(1-\frac{\omega^2}{\omega'^2}\right)=H.$$

In the Giffard injector we make

$$\frac{\omega}{\omega'}=0,16.$$

whence

$$\frac{\omega^2}{\omega'^2}=0,0256,$$

consequently

$$\frac{V^2}{2g}\times 0,9744=H.$$

But we should be able to give to the

ratio $\frac{\omega}{\omega'}$ greater value, and we can always assume approximately :

$$\frac{V^2}{2g}=H.$$

The condition that the liquid jet, through the tube E E, is uninterrupted assumes that the jet is at too low a temperature to be transformed into steam at the atmospheric pressure in its passage through the chamber G G. Hence its temperature should be below 100°.

Should the temperature exceed 100° the working of the apparatus is imperfect. We are warned by a production of steam which fills up the chamber G G and which escapes by the discharge pipe H H.

Then we should remove the pipe A of the contracted orifice D in order to increase the useful section of this orifice, or, we should lessen the quantity of steam of the jet by diminishing the orifice A by the conical rod T. Thus the conditions of the proper working of the apparatus are:

1st. That all of the jet of steam A be condensed by affluent water;

2d. That the temperature of the mixture be lower than the temperature of corresponding saturation at the mean pressure of G.

In case that the chamber G communicates with the atmosphere, the temperature of corresponding saturation is 100°. But it might happen that there be any pressure in the chamber G. It may be higher or lower than the atmospheric pressure. We will make no special hypothesis upon its value.

Call t_0 the temperature of the boiler;

t the temperature of the jet of steam at the moment that it fills the chamber BB. This temperature will be the temperature of saturation corresponding to the mean pressure. It is easy to see that this pressure equals the atmospheric pressure diminished by the height of the column of water CC, if the feeding reservoir RR is lower, and augmented by this height if it is higher.

τ, the temperature of the liquid jet at

the moment that it enters the divergent tube EE. This temperature is lower than 100° when the chamber GG communicates with the atmosphere, which is the case in the Giffard injectors;

θ, the temperature of the water in the reservoir RR.

Suppose one kilogramme of saturated steam issuing from the pipe A and containing a proportion x of steam.

Let y be the weight of water which the kilogramme of steam raises and conveys from the reservoir RR.

Let v be the velocity of the steam jet in A;

V the velocity of the mixture at the entrance of the tube E. To solve the problem we will write two equations.

1st. We assume that since there is no heat lost or gained by the material of the apparatus, the sum of internal heat augmented by the calorific equivalent of the living force has not changed during the phenomena; for this heat should always appear under the form of heat, or under the form of living force. This is

in accordance with the theorem of living force developed by the theory of heat.

2d. The theorem of rational mechanics relating to momentum is here applicable as it always is whatever the exchange of heat may be, for in the equation of this theorem the interior forces disappear. The amount of internal heat above 0^0 in a kilogramme of steam of the jet A is:

$$\int_0^t ldt + (r - \mathrm{A}pu)x.*$$

---

* The internal heat of any humid vapor, that is, part liquid and part vapor, is determined as follows:

Let x=the weight of the vapor in a kilogramme of the mixture.

Then $1-x$ the weight of the water in a kilogramme of the mixture.

Then the excess of internal heat of the vapor at t^0 compared with water at 0^0 is,

$$(r+\mathrm{L}-\mathrm{A}pu)x.$$

In this expression,

L is the quantity of heat required to raise a kilogramme of the liquid from 0^0 to t^0 when in contact with its vapor.

The calorific equivalent of the living force has for value $\frac{Av^2}{2g}$.

The total quantity of heat is

$$\frac{Av^2}{2g} + \int_o^t ldt + (r - Apu)x.$$

The internal heat of the affluent water is

$$y \int_o^\theta ldt.$$

A is the reciprocal of the Mechanical Equivalent of heat or $\frac{1}{424}$.

p is the pressure.

r is the latent heat of the vapor,

u is the excess of volume of the vapor over the liquid which yielded it.

pu is therefore our expression for work;

And Apu is its heat equivalent.

Now, as the latent heat liquid in the vapor is $L(1-x)$, the total internal heat,

$Q = L(1-x) + (r + L - Apu)x.$

$= L + (r - Apu)x.$

Or if l is the specific heat of the liquid at the temperature $t°$, then

$$L = \int_o^t ldt$$

$$Q = \int_o^t ldt + (r - Apu)x.$$

The living force is almost nothing and may be neglected; the internal heat augmented by the calorific equivalent of the living force before the mixture, will be then

$$\frac{Aw^2}{2g} + \int_o^t ldt + (r - Apu)x + y\int_o^\theta ldt.$$

The mixture forms, the steam is completely condensed, there is a diminution of volume and production of negative mechanical work. The total internal heat is augmented by the calorific equivalent of the work corresponding to the condensation, and which is

$$Apux.$$

When the mixture passes through the contracted section D, the sum of the living force and of the internal heat is

$$\frac{Aw^2}{2g} + \int_o^t ldt + rx + y\int_o^\theta ldt \quad . \quad . \quad \text{(A)}.$$

The introduction commences in the tube EE, the total weight of the mixture is $(1+y)$, its internal heat, since it is entirely in a liquid state, is expressed by

$$(1+y)\int_o^t ldt,$$

And its living force is,

$$(1+y)\frac{AV^2}{2g},$$

since V is the common velocity.

The sum of internal heat above O, and of the calorific equivalent of the living force at the inlet of the tube EE, is therefore

$$(1+y)\left(\int_o^\tau ldt+\frac{AV^2}{2g}\right)$$

This new expression of the total heat should be equal to the expression in (A). We have the equation

$$\frac{Aw^2}{2g}+\int_o^t ldt+rx+y\int_o^\theta ldt=(1+y)\left(\int_o^\tau ldt+\frac{AV^2}{2g}\right) \quad . \quad . \quad (B)$$

Now in consequence of the fundamental formula for the cooling of vapors, we have

$$\frac{Aw^2}{2g}=\int_t^{t_o} ldt+r_o x_o-rx,*$$

Substituting this value in the preced-

* r_o and r designating the quantities of heat of vaporization at the temperatures t_o and t.

ing equations it gives, after some transformations,

$$\int_{\theta}^{t_0} l dt + r_0 x_0 = (1+y)\left(\int_{\theta}^{\tau} l dt + \frac{AV^2}{2g}\right) \text{(C)}$$

This is the equation of living force. We will now establish the equations of momentum. We shall have them due to the contracted section D,

$$\omega V,$$

for this section is necessarily equal to that of the inlet of the tube EE and the weight of water has for its value

$$1000\omega V.$$

Its mass is

$$\frac{1000\omega V}{g}$$

In short, the expression for momentum is

$$\frac{1000\omega V}{g} V = \frac{1000\omega V^2}{g}$$

The amount of work of the affluent water from the reservoir RR may be neglected. As for the steam jet A, the amount delivered per second is evidently equal to that of the final mixture divided by $(1+y)$, and its velocity is w and its

quantity of work is therefore, before its passage into section D

$$\frac{1000\omega}{g} V - \frac{w}{1+y}.$$

and we find also for the increase of the momentum during a second from one side to the other of the contracted section D

$$\frac{1000\omega}{g} V\left(V - \frac{w}{1+y}\right)$$

Let us call π the pressure per square meter in the chamber GG, which is equal to the atmospheric pressure in the Giffard injectors, and P the pressure in the chamber BB which is equal to the atmospheric pressure diminished or increased by the column of water CC according as the supply reservoir RR is below or above the apparatus.

The contracted section D separates the jet into two parts, that above being subjected to the pressure P, and that below to the pressure π. The impulse of exterior forces during the exchange of velocities will be, per second

$$(P - \pi)\omega,$$

We have then, in accordance with the principle of equality of moments

$$\frac{1000\omega}{g}V\left(V-\frac{w}{1+y}\right)=(P-\pi)\omega,$$

Whence

$$V\left(V-\frac{w}{(1+y)}\right)=\frac{(P-\pi)g}{1000}. \quad . \quad . \quad . \quad (D)$$

The two equations (C) and (D) include the theory of steam injectors.—I copy here:

(C)

$$\int_{\theta}^{t_0} ldt+r_0x_0=(1+y)\left(\int_{\theta}^{\tau} ldt+\frac{AV^2}{2g}\right),$$

$$V\left(V-\frac{w}{1+y}\right)=\frac{(P-\pi)g}{1000}. \quad . \quad . \quad . \quad . \quad (D)$$

GIFFARD INJECTORS FOR FEEDING BOILERS.

In the Giffard injector (Fig. 1) the reservoir R R is ordinarily near the chamber B B, the pressure P is nearly equal to the atmospheric pressure, and as the chamber G G is in communication with the atmosphere,—we can take

$$P=\pi,$$

and we ought to have

$$\tau < 100^{0}.$$

Equation (D) of the moments reduces to

$$V - \frac{w}{1+y} = 0,$$

whence

$$V = \frac{w}{1+y}.$$

Take now the equation (C). In the second member of that equation we may neglect the term $\frac{AV^2}{2g}$

In effect the range of temperature τ and θ is always large enough. The following table demonstrates that V varies almost precisely as the difference $(\tau - \theta)$:

The equation (C) gives then approximately,

$$1+y = \frac{\int_{\theta}^{t_0} l dt + r_0 x_0 - \theta}{\tau - \theta} \quad . \quad (E)$$

Under this form we observe that y diminishes as τ increases. The mini-

Weight of Water Raised and Injector for

Value of θ	Temperature of the Mixture.	Pressure: 5 Atmospheres. (152°,22), $w=714^m$. Weight of Water raised per kilogr'm of steam suppos'd to be dry y	Velocity of the Mixture per second. V	Height to which the jet is raised. $\frac{V^2}{2g}$
		k.	m.	m.
$\theta=13°$	100	6,35	97,29	482,3
	80	8,55	74,87	285,7
	60	12,61	52,54	140,7
	40	22,70	30,17	46,4
	20	90,42	7,82	3,12
	13	∞	0	0
$\theta=50°$	100	11,06	59,29	179,2
	80	19,10	35,57	64,5
	60	59,50	11,85	7,17
	50	∞	0	0

Velocity of Mixture in Giffard Feeding Boilers.

sure of the Boiler.

	3 Atmospheres. (133°,91), w=596^m.			
Mechanical Work produced. $y\frac{V^2}{2g}$	Weight of Water raised per kilogr'm of steam suppos'd to be dry y	Velocity of the Mixture per second. V	Height to which the jet is raised. $\frac{V^2}{2g}$	Mechanical Work produced. $y\frac{V^2}{2g}$
km.	k.	m.	m.	km.
3063	6,29	81,73	340,5	2141
2443	8,47	62,94	201,9	1710
1774	12,50	44,15	99,4	1242
1053	22,50	25,36	32,8	737
282	89,63	6,57	2,21	197
0	∞	0	0	0
1981	10,95	49,88	126,8	1389
1232	18,92	29,95	45,6	864
425	58,74	9,97	5,07	298
0	∞	0	0	0

mum of y corresponds then with the maximum of τ, that is to say, at 100°.

We see also that y increases when θ increases; that is to say, in proportion to the heat of the feed water.

y increases in the same proportion that the temperatures τ and θ approach each other in value. Consequently when $\theta=100°$ y is infinite.

Experience demonstrates that the action of the injector ceases before reaching this limit, at about 70°.

We are able then to state the following propositions.

1st. The proportion of conveyed water increases and, consequently, the velocity of the mixture diminishes when the temperature of the water in the supply reservoir is raised.

2d. The proportion of conveyed water increases when the temperature of the mixture dimimishes. It is a minimum when the temperature of the mixture is of 100°. The velocity then attains its maximum.

3d. It diminishes, on the contrary,

UNIVERSITY OF CALIFORNIA ENGINEERING LIBRARY

when the steam is not dry and the proportion of water which it contains increases.

On pages 20 and 21 is a table of the values of y and of V for the boiler pressures of five and three atmospheres and the temperatures of 13° and 50° of the feeding water, the steam being dry.

The proportion of water raised increases rapidly as the temperature τ of the mixture diminishes.

The velocity diminishes in nearly the same ratio.

The quantity of water raised corresponding to the boiler pressures five atmospheres and three atmospheres are nearly the same, but the velocities are widely different. If we would have the velocity, and, consequently, the composition of the mixture corresponding to the pressure of the boiler, we must make

$$\frac{V^2}{2g} = \begin{matrix} 41{,}32 \text{ for five atmospheres,} \\ 20{,}66 \text{ for three atmospheres,} \end{matrix}$$

whence

$$V = \begin{matrix} 28^m{,}50 \text{ for five atmospheres,} \\ 20^m{,}15 \text{ for three atmospheres.} \end{matrix}$$

These numbers correspond to

$$y = \begin{matrix} 24{,}06 \text{ for five atmospheres,} \\ 31{,}02 \text{ for three atmospheres.} \end{matrix}$$

The temperature of the mixture is nearly 40° if the temperature of the feed-water is 13°.

ACTION OF THE GIFFARD INJECTOR.

There are two ways of considering the action of the Giffard injector. We measure the mechanical work performed without taking into account the heat carried away by the mixture; or, with taking this heat into account.

Following the last mode of operation, which is the only rational one, when employed in feeding the boiler the injector performs good service. It is clear that, since there is no loss of heat outside, and that the final living force is nothing, all the heat carried away by the steam jet is restored in the mixture, excepting that corresponding to the mechanical work accomplished, $\frac{AV^2}{2g}y$. Equation (C) is the mathematical expression of this fact.

It is not necessary to take into account the friction in the tubes, if we consider them impervious to heat, for the friction produces heat which is not lost by external radiation, but is found in the internal heat of the mixture.

The quantity of heat augmented by the living force in the mixture at the moment of its entrance into the convergent tube counted above, the temperature θ (which is the exterior temperature, and which serves as the starting point for the temperature in the equation (C)) is

$$(1+y)\left(\int_o^\tau ldt+\frac{AV^2}{2g}\right).$$

The portion $(1+y)\frac{AV^2}{2g}$ represents the heat equivalent of the living force of the mixture. This living force in part disappears in the work of introduction into the boiler. If things are so regulated that the height $\frac{V^2}{2g}$ precisely correspond to the relative pressure of the boiler, the living force $(1+y)\frac{V^2}{2g}$ is

effectually destroyed by the back pressure of the boiler; the introduction into the boiler will have no velocity, and the quantity of heat introduced will be definitely

$$(1+y)\int_{\theta}^{\tau} ldt$$

or about

$$(1+y)\ (\tau-\theta).$$

If the velocity V of the mixture is greater than that which corresponds to the relative pressure H, of the boiler, (measured by a column of water) the mixture will posess a certain living force

$$\frac{V^2}{2g}-H,$$

at its entrance into the boiler, but this living force becomes heat, in the motions which it occasions, so that no more heat can disappear than the quantity

$$AH\ (1+y).$$

Thus we know whatever the velocity V of the mixture there will disappear only the quantity of heat corresponding to the work

$$(1+y)\ H,$$

of the introduction into the boiler. This work comprises two terms :

$$y\,\mathrm{H} \text{ and } 1 \times \mathrm{H}.$$

The first represents the useful work in feeding; the second corresponds in reality to a quantity of heat which ought to be found in the heat of the mixture; this is a loss which is balanced by a previous gain made by the steam at the moment of exit from the boiler.

Suppose, then, that the velocity V of the mixture be precisely that which gives

$$\frac{V^2}{2g}=\mathrm{H},$$

so that the introduction of the mixture into the boiler be made without velocity; determine, by experiment, the quantity of water raised y, its temperature τ^1 and calculate the same temperature by the formula (E). The heat which should be brought back to the boiler, is, theoretically

$$(1+y)\ (\tau-\theta),$$

The heat brought back is, in reality,

$$(1+y)\ (\tau'-\theta).$$

There is then, practically, a loss of heat

$$(1+y)\ (\tau-\tau').$$

Add to this loss the loss of heat resulting from work accomplished

$$\frac{AV^2}{2g}y,$$

we have for total loss

$$(1+y)\ (\tau-\tau')+\frac{AV^2}{2g}y.$$

This waste of heat applied to the introduction of y kilogrammes of water into the boiler, gives for waste of heat per kilogramme:

$$i=\frac{1+y}{y}(\tau-\tau')+\frac{AV^2}{2g} \quad . \quad . \quad (F)$$

Here is an experiment given by M. Reech. M. Giffard succeeded in feeding a boiler at five atmospheres, by conveying a weight of water equal to fifteen times that of the steam. The temperature of the mixture was 48°, the affluent water being 13°. We have then, in this experiment:

$$\theta = 13°$$

$$y = 15.$$

The formula (E) gives

$$\tau = 53°,01.$$

Now then, the experiment indicates

$$\tau = 48°.$$

Consequently,

$$\tau - \tau' = 5°,01.$$

Now the waste of heat per kilogramme of feed water, is, (equation F):

$$i = \frac{16}{15} \times 5,01 + \frac{41,32}{424}$$

$$= 5,34 + 0,097 = 5.44 \text{ heat units.}$$

This number represents $\frac{1}{155}$ of the difference of temperature $(\tau - \theta)$.

This quantity of heat really disappears and is not found again. All other quantities of heat carried out of the boiler by the jet of steam y have been returned by the mixture.

Now, consider an ordinary supply pump, which introduces water into the boiler, at the temperature of 13°. This pump is operated by the engine, and produces useful work,

AH,

(H=height of water corresponding to the excess of the boiler-pressure over that of the condenser) per kilogramme of feeding-water, but it utilizes only a fraction k of force by reason of the friction or resistances of various kinds.

Now this force is only that of the steam; and we know that ordinary non-condensing steam engines use scarcely three parts in 100 of the heat transmitted to the boiler; then the introduction of a kilogramme of water into the boiler, by means of a feed-pump requires an expense of heat of

$$\frac{1}{0{,}03}\,\frac{AH}{k}.$$

The co-efficient k of the ordinary pump is 0,50, consequently this quantity of heat has for its value

$$66,6\ AH.$$

Observe that the water introduced is not of the temperature θ of the supply reservoir. To raise the temperature of this water from θ to τ it will be necessary to consume a quantity of heat

$(\tau-\theta)$, but as the heating apparatus never uses but $\frac{2}{3}$ of the heat developed by the combustion there will be $\frac{1}{3}$ of the heat lost. The total consumption of heat will be then,

$$j=66,6\ \mathrm{AH}+\tfrac{1}{3}(\tau-\theta).$$

By feeding by means of an injector, we had found the loss of heat to be,

$$i=0,155\ (\tau-\theta).$$

It is easy to see that the first is the more important. Suppose, for example, a pressure of five atmospheres, we will have:

$$\mathrm{H}=41,32,$$
$$\tau=48^{\circ},$$
$$\theta=13^{\circ},$$

$j=18.20$ heat units, $i=5.44$ heat units.

In this case, the cost of feeding by means of an injector is less than one-third of that of feeding by means of a pump.

These results would be somewhat modified if we had the use of a good condensing engine. Here the work of the engine is 10-100; that of the pump, if

well established, 60-100, introducing water from the condenser at a temperature of 50°. The injector should work equally with the water of the condenser. We should always have $y=15$.

The value of τ resulting from equation (E) would be

$$\tau=87^{\circ},70,$$

If we admit that the loss of heat by the injector will be more than 15,5-100 of the difference $\tau-\theta$ we will have for this loss

$$i=0,155\times 37,7=5 \text{ heat units, } 84.$$

The loss of heat from feeding by means of a pump, and of heating the water from 50° to 87°,70, will have for value

$$j=\frac{1}{0,10}\ \frac{AH}{0,60}+\frac{1}{3}(87,70-50)=14.12 \text{ heat units}$$

This is more than double the number 5.84 heat units. The economic advantage is always on the side of the Giffard injector; and this apparatus possesses also a great simplicity in adjustment and working, and an important economy of heat. The injector gains from nine to

thirteen *calorics* per kilogramme (heat units) of water introduced into the boiler.

THE GIFFARD INJECTOR EMPLOYED AS A PUMP.

The Giffard injector is a suction and forcing pump, but its mechanical performance is weak, because the greater part of the heat is employed in raising the temperature of the water. The expression of the mechanical rendering per kilogramme of wasted steam, is,

$$y \frac{V^2}{2g},$$

and its calorific equivalent

$$y \frac{AV}{2g}.$$

We have inserted in the table the values of the product $y \frac{V^2}{2g}$ for the different cases (pages 20, 21).

We see, by an inspection of the table, that the velocity of the mixture varies from 0 to 97^m, 29, that it corresponds to

the height of water from 0 to 482 metres. Consequently we are able to introduce water into a reservoir against a pressure of,

$$\frac{482}{10,33} = \text{about } 46 \text{ atmospheres.}$$

The mechanical work $y\frac{V^2}{2g}$ augments with the velocity. At the temperature 100° of the mixture, there are 3,063 kilogrammetres per kilogramme of wasted steam. If we compare this number with those of the preceding table, we see that it is only one-eighth of the theoretical work of steam in a non-condensing engine. The mechanical work would be only third of that which would be performed by a pump placed in the same conditions for the same purpose.

If we take the numbers corresponding to the temperature of 40° of the mixture, temperature for which $y = 22,70$, $V = 30,17$; the mechanical work produced is no more than 1,053 kilogrammetres.

It is reduced to the third of that which it was for $\tau = 100°$.

Considering, in a general manner, the Giffard injector as an exhausting pump, the problem ought to stand thus :

The height to which it is necessary to raise the water being given, what will be the mechanical performance of the injector ?

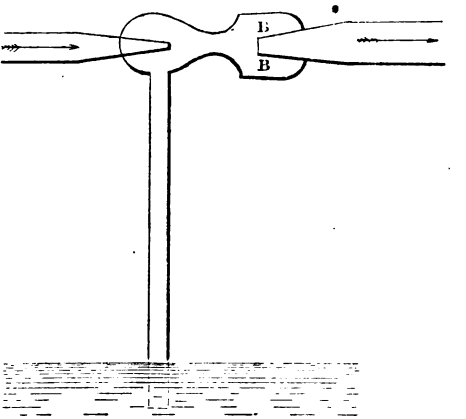


Fig. 2

At first sight it is clear that we wish to place the apparatus at the greatest possible height above the reservoir to be drained. In doing this we diminish the

pressure in the chamber BB, (Fig. 2). Consequently, we lower the temperature t of the steam jet, which is nothing more than the temperature of saturation corresponding to the pressure in the reservoir BB. The raising of the water into the chamber BB, will be the same as raising it in a suction pump. We should be able then to raise it to the ordinary practical limits, that is to say, eight metres. Under these conditions, there will be the greatest possible fall of the temperature of the steam from the boiler to the orifice of the injector. We shall have the maximum of mechanical effect, and there will be, between an injector working thus, and an ordinary feeding injector, when the steam is at about 100°, the same difference as between a condensing, and a non-condensing steam engine.

The height being eight metres, the pressure in the chamber BB will be

$$10{,}33 - 8^{m} = 2{,}33 \text{ of water}$$

or

$$176^{mm} \text{ of mercury.}$$

The temperature of corresponding saturation is about 63°. Going back to equations (D) (E), we will have for determining the minimum of the velocity of the mixture the equation

$$\frac{V^2}{2g}=h.$$

Equation (D) will give us

$$V\left(V-\frac{W}{(1+y)}\right)=-8g,$$

from these two equations we deduce

$$1+y=\frac{Vw}{V^2+8g}=\frac{\sqrt{hw}}{\frac{\sqrt{2g}}{h}+4.} \qquad (G)$$

The weight of water raised will be the greater as w will be greater. Now, the initial and final temperatures of the steam, during its flow, being determined, w depends only upon the moisture of the steam. The quantity of water raised will be greater in proportion as the steam is dry.

The mechanical work produced by the apparatus will be

$$\tau = y\,(h+8). \qquad \text{(H)}$$

Here is a table of quantities of water raised by an injector pump placed at eight metres above the exhausting reservoir, and fed by dry steam at five atmospheres:

	Injection of Dry Steam at 152°,82. Velocity, $v=930^{m}$.		
Total Height of Elevation.	Weight of Water raised per kilogram. of Steam used.	Mechanical Work obtained.	Temperature of Water raised.
$h+8$	y	W	τ
		km.	
1+8=9	41,0	369	..
10+8=18	46,37	835	..
50+8=58	26,47	1535	"
100+8=108	19,18	2071	"
200+8=208	13,51	2810	"
500+8=508	8,30	4216	"
800+8=808	6,89	5163	100°

This table shows that the mechanical performance of the injector pump increases

rapidly with great heights, otherwise it is inferior to ordinary steam pumps. It is then for great elevations that the injector gives most satisfactory results. It would be little economy to employ it in common use, but it would be very useful for draining exceptional leaks in mines, when the ordinary pumps are not sufficient. The extreme simplicity of this kind of apparatus will often give it the preference over others that do more perfect work.

We ought again to remark the importance of placing the injector at the height of eight metres above the reservoir. Whereas, in the first table we have found a performance of 3,063 kilogrammetres for an elevation of 482 ^{m},3 the injector being at the level of the reservoir; the table above gives us a performance of 4,216 kilogrammetres for a height nearly equal to the former—that is to say, 508 metres.

DRAINING SMALL DEPTHS WITH THE INJECTORS.

Steam injectors are employed at the side of vessels for draining leaks in the hold. Under these circumstances the total height of lifting varies from five to ten metres, and each kilogramme of expended steam furnishes about 900 kilogrammetres. Now, in a ship's engine, one kilogramme of steam produces about 17,000 kilogrammetres, according to M. Freminville's treatise on Marine Engines. A pump in the hold would perform only one fourth of this work, according to that, one kilogramme of steam would produce a useful work of 4,250 kilogrammetres.

Compare the number 900 kilogrammetres with this last, and we shall find the ratio of the work of the steam injector to that of the pump,

$$\frac{900}{4250}=0,211.$$

According to M. Freminville, this number should, in practice, be diminished to 0,16.

MEANS OF AUGMENTING THE PERFORMANCE OF THE INJECTOR PUMP.—WATER INJECTORS.

We should consider two reservoirs of water R and R′ (Fig. 3) placed at the heights, respectively H and *h*, above a

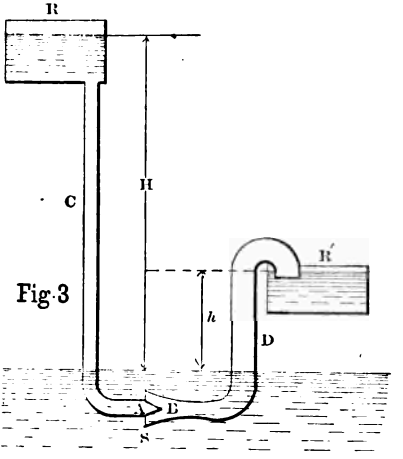


Fig. 3

reservoir S. R serves to raise the water from S, and discharge it into R′. Let us place below the reservoir R a vertical tube C, terminating in a nozzle A,

entering into a funnel-shaped opening of a second vertical tube D, leading to the reservoir R′. If we open the stopcock of the tube C, the water will run out by the nozzle A with great velocity, carrying a part of the surrounding liquid, and if the apparatus is well regulated, it will be able to raise the water to the height of the tube D, and it would flow into the reservoir R′. The fluid vein proceeding from the upper reservoir R will, by communicating its motion to the water of the reservoir, carry it on to R′. We will consider the condition of the working of the apparatus.

Let P be the weight of water delivered at the nozzle A;

P′ the weight of water carried per second;

v the velocity of the water leaving the nozzle;

u the velocity of the water at its entrance into the tube B.

Suppose the velocity of the affluent water about the tube B to be neglected,

the interchange of quantities of motion will give us the equation

$$Pv=(P+P')u \quad . \quad . \quad . \quad (I)$$

Suppose that the water falls into the reservoir R′ without appreciable velocity, then all loss of living force will be avoided, consequently the velocity u will be determined by the condition

$$\frac{u^2}{2g}=h,$$

whence

$$u=\sqrt{2gh} \quad . \quad . \quad . \quad . \quad (J)$$

but

$$v=\sqrt{2gH} \quad . \quad . \quad . \quad . \quad (K)$$

To be sure we neglect the friction. Substitute these values of u and v in equation I, and we have

$$P\sqrt{2gH}=(P+P')\sqrt{2gh},$$

whence

$$\frac{P'}{P}=\frac{\sqrt{H}-\sqrt{h}}{\sqrt{h}} \quad . \quad . \quad . \quad (L)$$

To ascertain the modulus of such an engine, it will be necessary to divide the useful work

$$W_u=P'h,$$

by the motor work or propelling force,

$$W_m = P\,(H-h).$$

This will give:

$$\rho = \frac{P'}{P}\cdot\frac{h}{H-h} = \frac{\sqrt{H}-\sqrt{h}}{\sqrt{h}}\cdot\frac{h}{H-h} = \frac{\sqrt{h}}{\sqrt{H}+\sqrt{h}}$$

or again,

$$\rho = \frac{1}{1+\sqrt{\frac{H}{h}}} \quad . \quad . \quad . \quad (M)$$

The elevation H is necessarily higher than that of h. The minimum of ratio $\frac{H}{h}$ is 1, hence the useful mechanical work will always be less than $\frac{1}{2}$.

We have supposed that the conveyed water comes to the nozzle A with no velocity. This is not so; and to make it more easily understood, we will take a very large funnel MN (Fig. 4).

If the suction of the tube at M differs but little from that at R, it is clear that the velocity of the water carried will be quite sensible.

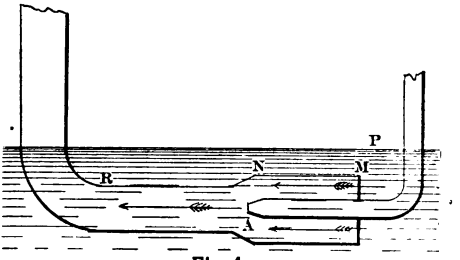


Fig. 4

Call this velocity v'. The equation (I) should be written in the following manner:

$$Pv+P'v'=(P+P')u \quad . \quad . \quad (N)$$

Since the apparatus is placed nearly at the surface of the water in the discharging reservoirs, the flow of water between the two points M and N can be produced only by difference of pressure. At M we have atmospheric pressure augmented by the slight height of water MP. At N we should have atmospheric pressure diminished by a small amount. If we call x this difference or *depression* expressed in head of water, we shall have

$$v'^2=2gx \quad . \quad . \quad . \quad . \quad (O)$$

The velocity v of discharge at the nozzle A will be given by the equation

$$v^2 = 2g(h+x) \quad . \quad . \quad . \quad (P)$$

and the common velocity of the water mixed in the tube R should satisfy the relation

$$u^2 = 2g\ (h+x) \quad . \quad . \quad . \quad (Q)$$

In short, if we call ω, Ω, O, the sections of the pipe and of the tube at M and at R, we shall have the relations:

$$\left.\begin{aligned} P &= 1000\ \omega\ v \\ P' &= 1000 \Omega\ v' \\ P + P' &= 1000\ O\ u \end{aligned}\right\} \quad . \quad . \quad . \quad (R)$$

which gives the following:

$$O\ u = \omega\ v + \Omega\ v'.$$

The heights H, h and the weight P being given, the equations (N), (O), (P), (Q), (R), will allow us to calculate seven unknown quantities

$$P', \quad v, \quad v', \quad u, \quad \omega, \quad \Omega, \quad O, \quad x.$$

Here are eight unknown quantities. One of these is to be determined before

solving the problem. It is the value x of the difference of pressure, mentioned above, and which varies with the adjustment of the apparatus.

The formula expressing the work indicates in what way this value varies.

The useful work is

$$W_u = P'h,$$

and the motor work or propelling force

$$W_m = P\,(H-h).$$

The rendering of the system is then

$$\rho = \frac{W_u}{W_m} = \frac{P'}{P}\,\frac{h}{H-h}.$$

Now, from equations (N), (O), (P), (Q), we deduce:

$$\frac{P'}{P} = \frac{v-u}{u-v'} = \frac{\sqrt{H+x}-\sqrt{h+x}}{\sqrt{h+x}-\sqrt{x}}. \quad . \quad . \quad (S)$$

Substitute in the value of ρ, it becomes:

$$\rho = \frac{\sqrt{H+x}-\sqrt{h+x}}{\sqrt{h+x}-\sqrt{x}}\,\frac{h}{H-h}$$

$$= \frac{\sqrt{h+x}+\sqrt{x}}{\sqrt{H+x}+\sqrt{h+x}},$$

or again,

$$\rho = \frac{1+\sqrt{\frac{x}{h+x}}}{1+\sqrt{\frac{H+x}{h+x}}} \quad . \quad . \quad . \quad (T)$$

If we compare this formula with (M), we discover that they are the same, when we make $x=0$. This supposes the velocity $v'=0$. It is easy to prove that the performance (T) increases with the difference x, and that it is always less than 1. We shall have the theoretical limit of its value in making $x=10^{m},33$. This difference may be artificially made by raising the injector above the reser-

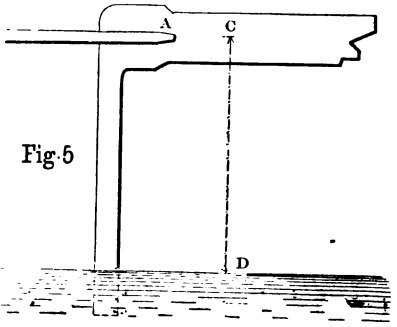


Fig. 5

voir (Fig. 5), which will force the water to rise to the height C D.

Suppose

$$P=1, \quad H=500^m, \quad h=5^m.$$

If, at first, we suppose the depression to be nothing, the equations (L) and (M) give us:

$$P'=\frac{\sqrt{500}-\sqrt{5}}{\sqrt{5}}=9,$$

$$\rho=\frac{1}{1+\sqrt{100}}=0{,}091.$$

To arrange the apparatus in a way to realize a depression of five meters, we make $x=\rho$ in equations (S), (T), and we have:

$$P'=\frac{\sqrt{505}-\sqrt{10}}{\sqrt{10}-\sqrt{5}}=20{,}85,$$

$$\rho=\frac{1+\sqrt{\frac{5}{10}}}{1+\sqrt{\frac{505}{10}}}=0{,}211.$$

By this hypothesis the performance will have more than doubled. The ar-

rangement of the apparatus has then a great influence upon its action. It should be so that the water raised arrives with considerable velocity at the injector. For this object we direct currents of water by means of several successive funnels (Fig. 6).

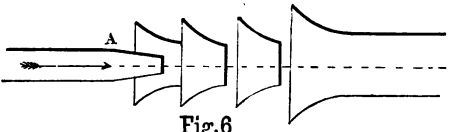


Fig.6

This arrangement is found in several machines of English origin.

We readily understand that the jet of a steam injector may be used as a water injector.

A steam injector conveys, for example, fifteen kilogrammes of water per kilogramme of steam discharged, and communicates a velocity capable of surmounting a pressure of five atmospheres. In other words, the height to which the jet will be able to rise is $41^{m},32$.

If we make this liquid jet pass through the nozzle A in Figs. (3) (4), (5), (6),

we will be able to carry a new quantity of water, which, it is true, is not raised so high. But if it is not necessary to raise the water above five meters to reach the 41,^{m}32, it is clearly to our interest to adopt this arrangement.

The same considerations which we have recommended to place the injector above the supply reservoir are applicable here.

We will now give an account of the theoretical performance of the apparatus in (Fig. 7).

The proportion of water carried by the steam jet is reckoned from the height at which the injector is placed above the discharging reservoir, from the pressure of the boiler and from the amount of water practically raised. Equations (D) and (E) will furnish the proportion of water carried and the velocity of the mixture. The reservoirs B and C being at the same pressure, that is to say, the atmospheric pressure diminished by the height A R, the equation (B) will give:

$$v = \frac{w}{1+y}.$$

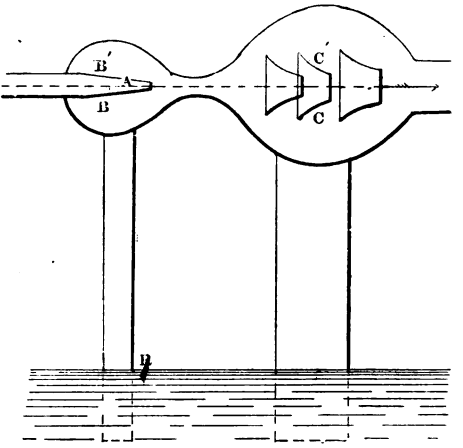


Fig. 7

Knowing the velocity v of the liquid jet at its entrance into the chamber C, we calculate the weight of water carried by the jet by means of formula (S), in giving a start to the depression x, and in calculating the dimensions of the suction apparatus by means of equation (R). We will remember in equation (O) that the velocity v' represents the projection upon the axis of the jet, of the real ve-

locity of the raised liquid streams. It will be necessary, then, to take into account the angle at which the funnels taper.

It is practice alone which can determine the best arrangement of this apparatus, whose theoretical principles only we have established.

We will show by an example how these theoretical calculations may be made.

Example.—To raise the water from the hold of a vessel, knowing the height of suction to be five meters; and the fall of the discharge, five meters. The pressure of the boiler is three atmospheres.

The table (3) gives us for the velocity of the flow of dry steam of three atmospheres at $\frac{1}{2}$ atmosphere final pressure, 739 meters. It will be $w=739$. We will then have equation (D):

$$v=\frac{w}{1+y}.$$

If we make $y=20$, we will find:

$$v=\frac{739}{21}=35^{m},20.$$

Velocity of Flow of Dry Steam Pres-

The velocity of a mixture of steam and water, may be obtained by multiplying

Pressures and Final Temperatures.		Pressures		
		8 at. 170°,81	7 at. 165°,54	6 at. 159°,22
Press-ures.	Temper-ature.	485,79	489,71	494,11
atmos.	degrees.	meters.	meters.	meters.
7	165,34	223	..	..
6	159,22	325	238	..
5	152,22	411	349	258
4	144,00	494	445	381
3	133,91	580	540	490
2,4	126,46	636	601	558
2	120,60	676	645	606
1,8	117,30	698	668	632
1,6	113,69	721	694	658
1,4	109,68	746	719	686
1,2	105,17	773	748	717
1,00	100,00	803	779	750
0,90	97,08	819	797	769
0,80	93,88	837	815	788
0,70	90,32	856	835	809
0,60	86,32	877	857	833
0,50	81,71	900	882	858
0,40	76,25	928	910	888
0,30	69,49	960	944	924
0,20	60,45	1,002	988	969
0,10	46,21	1,065	1,052	1,037

UNDER DIFFERENT INITIAL AND FINAL SURES.

water, containing x of steam and $1-x$ of the numbers of the table below by $\sqrt{x}$.

and Initial Temperatures.

5 at. 152°,22	4 at. 144°,00	3 at. 133°,91	2 at. 120°,60	1 1/2 at. 111°,74
499,13	545,02	512,22	521,70	527,99
meters.	meters.	meters.	meters.	meters.
..	..	..	..	..
..	..	..	..	..
..	..	..	..	..
283	..	..	..	..
421	349	..	..	..
501	420	279	..	..
555	485	372	..	..
584	519	417	190	..
613	553	460	276	..
645	588	504	347	..
678	625	549	463	274
714	666	596	477	366
734	688	621	498	409
755	710	647	543	451
777	735	676	578	494
802	763	706	615	539
830	792	739	655	585
861	826	770	699	636
899	866	821	751	694
947	918	877	814	765
1,017	993	958	906	865

The height designated by H is here:

$$\frac{v^2}{2g}=H=63^m,18.$$

Since the pressure which exists in chamber C about the funnels, is only $\frac{1}{2}$ atmosphere, we will be able to realize at the axis of the jet only a slight depression; we will suppose two meters. It will be, then, $x=2$, and we will have equation (S):

$$\frac{P'}{P}=\frac{\sqrt{63,18+2}-\sqrt{5+2}}{\sqrt{5+2}-\sqrt{2}}=4,41.$$

The weight of water positively raised then will have been:

$$4,41\times 20=88^k,20,$$

per kilogramme of discharged steam. The mechanical work produced has for its value:

$88^k,20\times 10^m=882$ kilogrammeters, per kilogramme of steam.

The table (1), that for a weight of water raised to $89^k,63$, which is nearly equal to 88,20; the Giffard injector produces only 197 kilogrammeters. If we

keep the injector at five meters above the surface of the water to be raised, and make use of this apparatus without the intervening injector of water, we should calculate the weight of water carried in the following manner. We should have for the necessary velocity to cause the jet to attain to five meters of height of discharge:

$$v=\sqrt{2g\times(5+5)}=14 \text{ meters},$$

$$1+y=\frac{739}{14}=52{,}80,$$

whence

$$y=51{,}80.$$

The weight of water varied would be only $51^{k},80$, in place of $88^{k},20$, which we have found in employing the water injector.

The steam injector arranged with a water injector to serve as a pump, has then a notable advantage over one used solely for steam. Several machines founded on these principles are used in England for draining mines. The preceding considerations demonstrate that

the employment of these machines is not very convenient. Their use is justified only when it is necessary to accomplish rapid drainage with simple apparatus.

EJECTOR CONDENSERS.

Let us conceive that we put an injector on the escape pipe of a condensing engine. The apparatus will work as usual, that is to say, according as the escaped steam arrives it becomes condensed by the contact with the cold water furnished by the reservoir, will maintain a vacuum, and the mixture of water with the condensed steam imparting a great velocity will be capable of surmounting the excess of exterior atmospheric pressure over the pressure of escaping steam.

We shall thus be able, by the simple interposition of the injector apparatus, to supplant the air pump and all the accessories, and we shall economise the work absorbed by this pump, often very considerable.

Such is the principle of ejector con-

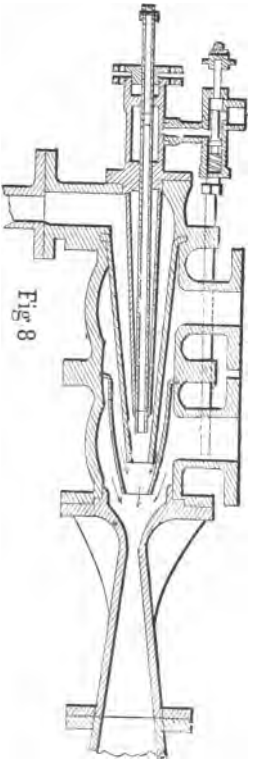


Fig 8

densers, the employment of which tends, probably, to become general.

Professor Rankine has reported the experiments made in 1868, upon a condenser ejector of the Morton system. The apparatus (Fig. 8) differs from ordinary steam-injectors in that the cold water is drawn by the central tube; the escape of steam is distributed about the central jet by the very long and concentric funnels. In this way the living force of the cold water suffers no loss.

This living force is considerable since the presssure which exists about the cold water, at the moment in which it mixes with the jet of steam, is necessarily less than the pressure at the escape, without which the steam would not flow out, so that the water possesses the velocity due to the excess of the atmospheric pressure over the pressure of the escape.

In the above named experiments Prof. Rankine has found the following results:

	Per sq. centimeter.
Absolute pressure at the boiler.	3^k,427

Absolute pressure at commencement of escape.....	$0^k,756$
Mean pressure maintained behind the pistons by the condenser ejector.....	$0^k,299$
Pressure kept near the funnels.	$0^k,210$
	Centigrade.
Temperature of cold water....	8°,4
Temperature of water of condensation	30°,3
Weight of cold water employed per kilogramme of steam....	$28^k,40$

These results are, as we see, very satisfactory. They are not widely different from those which were obtained by the air-pumps, but these latter require a notable expenditure of moving force.

In the machine experimented, Rankine valued the effective force at twenty-four horses, and the economy realized by the replacing one horse power air-pump at four per cent.

The theory of the condenser ejector does not differ from that of ordinary injectors, only there has been no account taken of the velocity at which the cold water arrives, that here has considerable

value, which is neglected in our general equation (C). To take account of it, we should add to the first member of this equation a term

$$\frac{AU^2}{2g}y,$$

representing the living force of the weight of water y.

In reality we will be able to neglect the term $\frac{V^2}{2g}$.

The determination of the velocity and the calculation of the dimensions of the apparatus are made, according to the method heretofore explained. This is a problem which presents no difficulties.

The Morton apparatus has one peculiarity which we ought to describe. To put the apparatus in motion, we allow a priming of steam from the boiler to pass through a central tube. It may happen that the pressure falls below the proper limits, for the working of the apparatus. Under these circumstances, the cold water flows into the escape-pipes, and

then into the cylinders. Every time that this inconvenience threatens the central steam jet is automatically opened by a spring piston, and its power communicates to the cold water jet a sufficient impulse to prevent its deviation towards the cylinders, and re-establishes the normal working of the machine.

THE INJECTOR EMPLOYED IN A HYDRAULIC PRESS.

Suppose that we place an injector at the foot of a cylinder of a hydraulic press (Fig. 9). The jet of hot water may be introduced into the cylinder so that the pressure will be lower than that which corresponds to the velocity of flow. We should be able then to work a hydraulic press with a pressure

$$\frac{V^2}{2g}.$$

Suppose the pressure at the boiler be five atmospheres, the jet according to table, pages 20 and 21, could rise to the height of 482 meters; this corresponds to

482,000 kilogrammeters per sq. meter, or to

50 atmospheres.

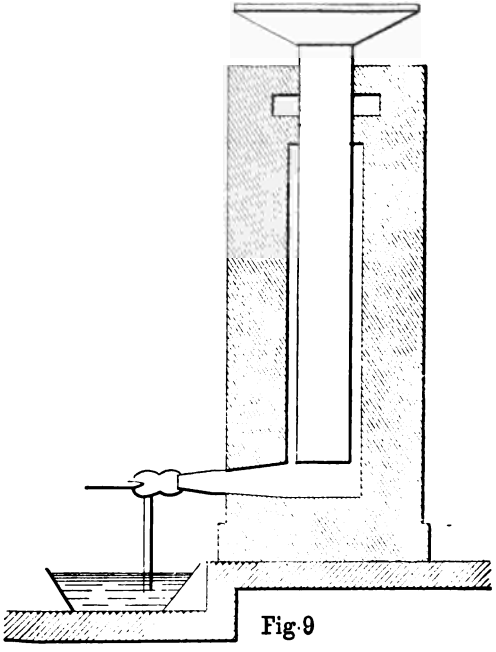


Fig. 9

The same table shows that the mechanical work realized in these conditions is only

3063 kilogrammeters,
per kilogramme of steam used.

The work diminishes in the same proportion as the pressure diminishes. Consequently, it would be better to work with high pressure and so diminish the diameter of the hydraulic press.

This is a novel application of the injector, and may prove of service in situations where a hydraulic press is necessary, and where a pump of sufficient power is wanting.

Such an application has not yet been made, at least to our knowledge, and needs preliminary experiments.

PUMPING GAS BY STEAM.—EXPLANATION OF THE FEEBLE WORKING OF FEEDING OR DRAINING INJECTORS.

That which causes the weakness of the performance of a steam injector employed as a draining pump, is the disproportion between the height to which a liquid mixture may be raised, which is several hundred meters, and the height to which we in reality raise them. The apparatus

does not give its maximum of performance excepting for very great heights. The disproportion which exists between the specific gravity of the body raised, which is here water, and that which is carried along with it, that is to say, steam, is another source of loss.

In effect, the relative velocity of the water raised at the moment when it mixes with the condensed steam, is so

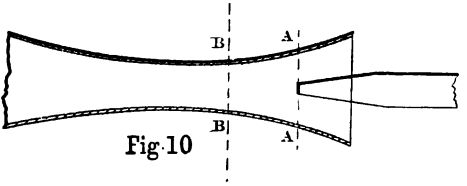


Fig. 10

slight that it is not worth taking into account. Let us suppose, on the contrary, that the steam escape in a gaseous medium which it will drag along by a sort of lateral friction (see Fig. 10), and as in a water injector. It may happen that the velocity of affluent air be considerable, consequently cannot be neglected.

Now this circumstance will augment the performance, just as in the water injector.

Let W be the velocity of the steam, w that of affluent air, v that of the supposed mixture in the contracted section B B, y the weight of air drawn per kilogramme of steam.

The momentum of the steam will be

$$\frac{W}{g},$$

that of affluent air,

$$\frac{w}{g}y,$$

that of the mixture,

$$(1+y)V.$$

Neglecting the difference of pressure in the sections A and B, we will have the following equation:

$$W+wy=(1+y)V,$$

whence we find

$$V=\frac{W+wy}{1+y}.$$

The living force of the steam was

$$\frac{W^2}{2g},$$

that of affluent air,

$$\frac{w^2}{2g}y,$$

that of air after the mixture,

$$\frac{V^2}{2g}y.$$

The performance of the apparatus will be then:

$$\rho=\frac{\frac{V^2}{2g}y}{\frac{W^2}{2g}}=\frac{y\left(1+\frac{w}{W}y\right)^2}{(1+y)^2}$$

When we suppose the velocity of the material drawn to be nothing, as that in the Giffard injector for feeding boilers, $w=0$, and the formula of the performance is reduced to

$$\rho'=\frac{y}{(1+y)^2}.$$

We see at once how feeble this action is when y is not very small.

When	$y=1$	$\rho'=\frac{1}{4}=0{,}25$
When	$y=15$	$\rho=0{,}058.$

If, on the contrary, the ratio $\frac{w}{W}$ be slightly increased, the term $\left(1+\frac{w}{W}y\right)^2$ will increase very sensibly the value of the mechanical performance.

For example.—If we make $y=15$ and $\frac{w}{W}=\frac{1}{6}$ the ratio realisable in practice, the calculations give $\rho=0,72$ in place of 0,058, which we have found in making $w=0$.

This simple discovery suffices to make us understand that steam injectors are more likely to give good results when employed as gas pumps than when used as water pumps.

LOCOMOTIVE EXHAUST.

The exhaust of a locomotive is only an application of preceding considerations. Only in these machines the steam jet is intermittent, notably augmenting the results which we should obtain with a continuous jet. People do not know

that the draught of the locomotive hearth is, if I may say so, due only to the escaping steam; this is, truly, the fundamental principle of the construction of these powerful machines.

Prof. Zeuner has demonstrated by calculation, and by experiment, that the weight of air drawn into the chimney of a locomotive is proportional to the weight of steam expended. So the combustion is more active when the engine works fastest.

It has been long known, in a general way, that the velocity of a locomotive engine ought to be pushed to its utmos limits when required to perform important work, as when ascending a slope.

Generally the proportion of the weight of air drawn to the weight of steam employed, is between 2 and 3 to 1.

M. Péclet reports the experiments made by M. Glépin upon the draught produced by the continuous steam jets opening into cylindrical tubes. The results are quite various, according to the diameter and the length of the tubes.

We have usually found that the performance increases with the length of the tubes. Its value has been a maximum with the tubes from $0^m,50$ to $0^m,55$ in diameter, and from 3 meters to $3^m,50$ in height. It was then raised to 0.1145. We here call performance the proportion of the living force of air drawn to the living force of the steam jet.

It seems demonstrated that the intermittent jets produce superior action, and according to M. M. Flachat, and Petiet the work produced by the intermittent injections of steam in the chimneys of locomotives varies from 0.5 to 0.16 of the work which the steam is able to produce.

Usually in this kind of apparatus it is necessary to multiply the surfaces of the contact of steam and air. Then annular jets are better adapted for such work than the compact cylindrical jets.

STEAM BLOWERS.

Several important processes are founded upon the conveying of air by a jet of

steam. This method has been applied to the ventilation of mines. It was also employed to ventilate the great machine gallery at the Paris Exposition, in 1867.

To conclude, M. Siemens has made a new application in the manufacture of steel. In his apparatus, the air is drawn by a double tube through an annular jet and a central conical jet. The air is introduced by an annular central orifice, and by orifices through the outside partition of the apparatus. The contacts of the fluid entering and the fluid escaping are thus greatly multiplied, and this circumstance is eminently favorable to the action.

The mixture of steam and air is introduced into a reservoir containing bits of coke crushed and washed by a current of cold water. The steam is condensed and the air escapes mostly free from steam.

As a means of forcing currents of air for purposes of ventilation this method of M. Siemens is worthy of consideration.

KÖRTING'S LOCOMOTIVE INJECTOR.

Locomotive injectors as hitherto constructed labor under the disadvantage of feeding with cold water only, and they can hardly be relied upon if the temperature of the latter exceeds 104 deg. Fahr. Even then they require the most careful adjustment of the water supply. The reasons for this defect may be traced to the principles upon which the injectors are constructed.

With an injector of correct proportions the certainty of action depends upon the velocity with which the water enters the space where the steam and water combine. In locomotive injectors to which the water can flow with only a very small pressure, this velocity depends mainly upon the vacuum produced in the condensing nozzle. This vacuum must be kept as high as possible. With *constant* steam pressure and temperature

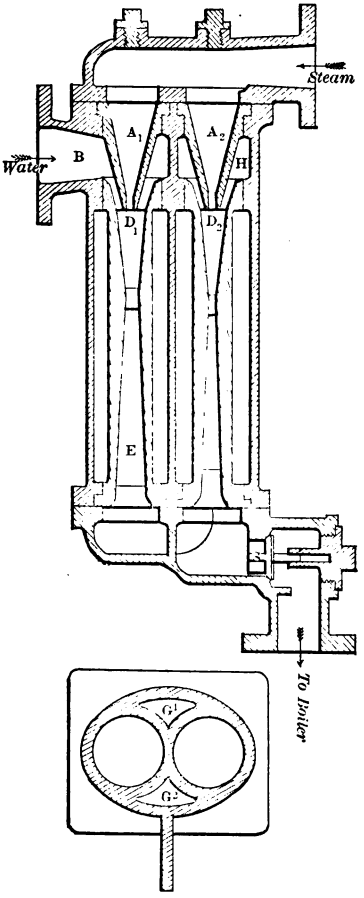
of water, the vacuum obtained is lower when the condensing nozzle is fed with too much or too little water; in the first case because the jet of steam has not sufficient power to impel the water which gives a back pressure; in the second case because the temperature of the mixture is not low enough, and consequently the vacuum is lessened. For these reasons the water supply requires to be very carefully regulated. With *variable* steam pressures and temperatures of the feed water, the vacuum becomes lower with increasing temperature of water and also with increasing steam pressure, as in both cases the temperature in the condensing space is raised, the maximum of which can be only 212 deg. Fahr. But at this point the certainty of action is *nil*; generally speaking, this temperature should not exceed 194 deg. Fahr. As the increase of temperature with high pressure steam is about 90 deg. Fahr., it follows that the feed water should not be hotter than 104 deg. Fahr. On this account many rail-

ways will not allow their drivers to warm the feed water in the tenders, as the reliability of the injectors increases with the coldness of the water, and certainty is of the first importance in railway management. This defect is almost entirely done away with in Körting's universal injector, which works with equal certainty at all pressures. This apparatus consists of two steam jet pumps combined. The second pump or real injector which forces the water into the boiler receives it from the primary or assistant injector under pressure, so that the second pump has only to overcome the difference in pressure existing between that of the boiler and that already overcome by the primary injector.

The required quantity of steam is therefore divided, and only a small portion of it used in the first part of the apparatus. Consequently the increase of temperature is much less than in ordinary injectors; the water entering it may therefore be much warmer without bring-

ing the temperature in the condensing space above 194 deg. Fahr., which is the maximum here as in ordinary injectors. The temperature of the feed-water may safely be as high as 158 deg. Fahr. A special feature of this primary injector is that with increased steam pressure it delivers, without regulation, more water at increased pressure to the second part of the apparatus.

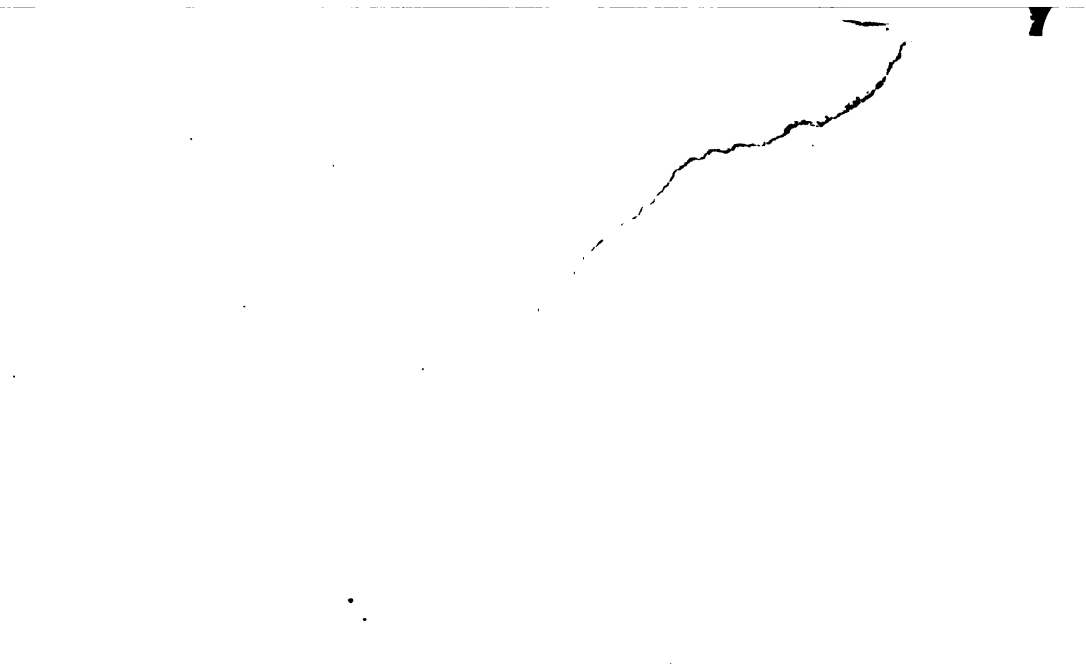
The second pump delivers into the boiler the water forced into it by the primary injector. The certainty of action of this second part of the apparatus depends upon the pressure with which it is fed by the assistant injector and not upon any vacuum. As with increasing steam pressure the velocity of the water entering the second pump is also increased, it follows that with the same temperature of feed-water, the reliability of this apparatus remains the same under all steam pressures, while with ordinary injectors it decreases as the steam pressure increases. On this account no water regulation is necessary. The tem-


Steam
Water
B
A1
A2
H
D1
D2
E
To Boiler
G1
G2

perature in the condensing space does not come in question with the second part of the apparatus; it may, if required, exceed 212 deg. Fahr., and in fact does exceed it, for with feed-water of 158 deg. Fahr., and 120 lbs. boiler pressure, the water fed into the boiler is actually 257 deg. Fahr. The apparatus therefore must not be provided with an overflow communicating with the atmosphere, as otherwise the high temperature would cause the formation of steam and an escape of water. The apparatus is started by opening a small cock behind the injector, similar to that with which other injectors are provided for letting the water out of the pressure pipe.

The foregoing illustration shows the Körting universal injector in longitudinal and cross sections. The working steam simultaneously enters the two steam nozzles A_1 and A_2 in the injector. The jet of steam from A_1 draws the requisite water through the pipe B, and forces it through the cone D_1 with corresponding velocity. This velocity is

transformed into pressure in the diverging tube E which communicates by means of the chambers G_1 and G_2 (see cross-section) with the space H of the second pump. From here the water enters under pressure the condensing space D_2, whence it is forced by the steam issuing from the nozzle A_2 into the boiler through the back pressure valve S. While starting the injector a cock communicating with space E_2 is opened till water escapes from it, after which it is slowly closed.



*** *Any book in this Catalogue sent free by mail on receipt of price.*

VALUABLE

SCIENTIFIC BOOKS,

PUBLISHED BY

D. VAN NOSTRAND,

23 MURRAY STREET AND 27 WARREN STREET,

NEW YORK.

FRANCIS. Lowell Hydraulic Experiments, being a selection from Experiments on Hydraulic Motors, on the Flow of Water over Weirs, in Open Canals of Uniform Rectangular Section, and through submerged Orifices and diverging Tubes. Made at Lowell, Massachusetts. By James B. Francis, C. E. 2d edition, revised and enlarged, with many new experiments, and illustrated with twenty-three copperplate engravings. 1 vol. 4to, cloth..... $15 00

ROEBLING (J. A.) Long and Short Span Railway Bridges. By John A. Roebling, C. E. Illustrated with large copperplate engravings of plans and views. Imperial folio, cloth..... 25 00

CLARKE (T. C.) Description of the Iron Railway Bridge over the Mississippi River, at Quincy, Illinois. Thomas Curtis Clarke, Chief Engineer. Illustrated with 21 lithographed plans. 1 vol. 4to, cloth..... 7 50

TUNNER (P.) A Treatise on Roll-Turning for the Manufacture of Iron. By Peter Tunner. Translated and adapted by John B. Pearse, of the Penn-

ylvania Steel Works, with numerous engravings wood cuts and folio atlas of plates..... $10

ISHERWOOD (B. F.) Engineering Precedents for Steam Machinery. Arranged in the most practical and useful manner for Engineers. By B. F. Isherwood, Civil Engineer, U. S. Navy. With Illustrations. Two volumes in one. 8vo, cloth..... $2 50

GILLMORE (Gen. Q. A,) Practical Treatise on the Construction of Roads, Streets, and Pavements. By Q. A. Gillmore, Lt.-Col. U. S Corps of Engineers, Brevet Major-Gen. U. S. Army. With 70 illustrations. 12mo, cloth..... 2 00

—— Report on Strength of the Building Stones in the United States, etc. 8vo, illustrated, cloth..... .... 1 50

CAMPIN on the Construction of Iron Roofs. By Francis Campin. 8vo, with plates, cloth..... 2 00

COLLINS. The Private Book of Useful Alloys and Memoranda for Goldsmiths, Jewellers, &c. By James E. Collins. 18mo, cloth..... 75

CIPHER AND SECRET LETTER AND TELEGRAPHIC CODE, with Hogg's Improvements. The most perfect secret code ever invented or discovered. Impossible to read without the key. By C. S. Larrabee. 18mo, cloth. 1 00

COLBURN. The Gas Works of London. By Zerah Colburn, C. E. 1 vol 12mo, boards..... 60

CRAIG (B. F.) Weights and Measures. An account of the Decimal System, with Tables of Conversion for Commercial and Scientific Uses. By B. F. Craig, M.D. 1 vol. square 32mo, limp cloth..... 50

NUGENT. Treatise on Optics; or, Light and Sight, theoretically and practically treated; with the application to Fine Art and Industrial Pursuits. By E. Nugent. With one hundred and three illustrations. 12mo, cloth..... 1 50

FREE HAND DRAWING. A Guide to Ornamental Figure and Landscape Drawing. By an Art Student. 18mo. boards,..... 50

HOWARD. Earthwork Mensuration on the Basis of the Prismoidal Formulae. Containing simple and labor-saving method of obtaining Prismoidal contents directly from End Areas. Illustrated by Examples, and accompanied by Plain Rules for Practical Uses. By Conway R. Howard, C. E., Richmond, Va. Illustrated, 8vo, cloth..... 1 50

GRUNER. The Manufacture of Steel. By M. L. Gruner. Translated from the French, by Lenox Smith, with an appendix on the Bessamer process in the United States, by the translator. Illustrated by Lithographed drawings and wood cuts. 8vo, cloth.. 3 50

AUCHINCLOSS. Link and Valve Motions Simplified. Illustrated with 37 wood-cuts, and 21 lithographic plates, together with a Travel Scale, and numerous useful Tables. By W. S. Auchincloss. 8vo, cloth.. 3 00

VAN BUREN. Investigations of Formulas, for the strength of the Iron parts of Steam Machinery. By J. D. Van Buren, Jr., C. E. Illustrated, 8vo, cloth. 2 00

JOYNSON. Designing and Construction of Machine Gearing. Illustrated, 8vo, cloth..... 2 00

GILLMORE. Coignet Beton and other Artificial Stone. By Q. A. Gillmore, Major U. S. Corps Engineers. 9 plates, views, &c. 8vo, cloth..... 2 50

SAELTZER. Treattse on Acoustics in connection with Ventilation. By Alexander Saeltzer, Architect. 12mo, cloth..... 2 00

BUTLER (W. F.) Ventilation of Buildings. By W. F. Butler. With illustrations. 18mo, boards 50

DICTIONARY of Manufactures, Mining, Machinery, and the Industrial Arts. By George Dodd. 12mo, cloth..... 1 50

BOW. A Treatise on Bracing, with its application to Bridges and other Structures of Wood or Iron. By Robert Henry Thurston, C. E. 156 illustrations, 8vo, cloth..... 1 50

BARBA (J.) The Culture of Steel for Constructive Purposes; Method of working, Applying, and Testing Plates and Brass. With a Preface by A. L. Holley, C. E. 12mo, cloth..... 1 50

GILLMORE (Gen. Q. A.) Treatise on Limes, Hydraulic Cements, and Mortars. Papers on Practical Engineering, U. S. Engineer Department, No. 9, containing Reports of numerous Experiments conducted in New York City, during the years 1858 to 1861, inclusive. By Q. A. Gillmore, Bvt. Maj.-Gen., U. S. A., Major, Corps of Engineers. With numerous illustrations. 1 vol, 8vo, cloth..... $4 00

HARRISON. The Mechanic's Tool Book, with Practical Rules and Suggestions for Use of Machinists, Iron Workers, and others. By W. B. Harrison, associate editor of the "American Artisan." Illustrated with 44 engravings. 12mo, cloth..... 1 50

HENRICI (Olaus). Skeleton Structures, especially in their application to the Building of Steel and Iron Bridges. By Olaus Henrici. With folding plates and diagrams. 1 vol. 8vo, cloth..... 1 50

HEWSON (Wm.) Principles and Practice of Embanking Lands from River Floods, as applied to the Levees of the Mississippi. By William Hewson, Civil Engineer. 1 vol. 8vo, cloth..... 2 00

HOLLEY (A. L.) Railway Practice. American and European Railway Practice, in the economical Generation of Steam, including the Materials and Construction of Coal-burning Boilers, Combustion, the Variable Blast, Vaporization, Circulation, Superheating, Supplying and Heating Feed-Water, etc., and the Adaptation of Wood and Coke-burning Engines to Coal-burning; and in Permanent Way, including Road-bed, Sleepers, Rails, Joint-fastenings, Street Railways, etc., etc. By Alexander L. Holley, B. P. With 77 lithographed plates. 1 vol. folio, cloth.... 12 00

KING (W. H.) Lessons and Practical Notes on Steam, the Steam Engine, Propellers, etc., etc., for Young Marine Engineers, Students, and others. By the late W. H. King, U. S. Navy. Revised by Chief Engineer J. W. King, U. S. Navy. Nineteenth edition, enlarged. 8vo, cloth..... 2 00

MINIFIE (Wm.) Mechanical Drawing. A Text-Book of Geometrical Drawing for the Use of Mechanics

and Schools, in which the Definitions and Rules of Geometry are familiarly explained; the Practical Problems are arranged, from the most simple to the more complex, and in their description technicalities are avoided as much as possible. With illustrations for Drawing Plans, Sections, and Elevations of Buildings and Machinery; an Introduction to Isometrical Drawing, and an Essay on Linear Perspective and Shadows. Illustrated with over 200 diagrams engraved on steel. By Wm. Minifie, Architect. Ninth edition. With an Appendix on the Theory and Application of Colors. 1 vol. 8vo, cloth..... $4 00

"It is the best work on Drawing that we have ever seen, and is especially a text-book of Geometrical Drawing for the use of Mechanics and Schools. No young Mechanic, such as a Machinists, Engineer, Cabinet-maker, Millwright, or Carpenter, should be without it."—*Scientific American.*

——— Geometrical Drawing. Abridged from the octavo edition, for the use of Schools. Illustrated with 48 steel plates. Fifth edition. 1 vol. 12mo, cloth.... 2 00

STILLMAN (Paul.) Steam Engine Indicator, and the Improved Manometer Steam and Vacuum Gauges—their Utility and Application. By Paul Stillman. New edition. 1 vol. 12mo, flexible cloth..... 1 00

SWEET (S. H.) Special Report on Coal; showing its Distribution, Classification, and cost delivered over different routes to various points in the State of New York, and the principal cities on the Atlantic Coast. By S. H. Sweet. With maps, 1 vol. 8vo, cloth..... 3 00

WALKER (W. H.) Screw Propulsion. Notes on Screw Propulsion: its Rise and History. By Capt. W. H. Walker, U. S. Navy. 1 vol. 8vo, cloth..... 75

WARD (J. H.) Steam for the Million. A popular Treatise on Steam and its Application to the Useful Arts, especially to Navigation. By J. H. Ward, Commander U. S. Navy. New and revised edition. 1 vol. 8vo, cloth..... 1 00

WIESBACH (Julius). A Manual of Theoretical Mechanics. By Julius Weisbach, Ph. D. Translated from the fourth augmented and improved German edition, with an Introduction to the Calculus, by Eckley B. Coxe, A. M., Mining Engineer. 1,100 pages, and 902 wood-cut illustrations. 8vo, cloth 10 00

DIEDRICH. The Theory of Strains, a Compendium for the calculation and construction of Bridges, Roofs, and Cranes, with the application of Trigonometrical Notes, containing the most comprehensive information in regard to the Resulting strains for a permanent Load, as also for a combined (Permanent and Rolling) Load. In two sections, adadted to the requirements of the present time. By John Diedrich, C. E. Illustrated by numerous plates and diagrams. 8vo, cloth..... 5 00

WILLIAMSON (R. S.) On the use of the Barometer on Surveys and Reconnoissances. Part I. Meteorology in its Connection with Hypsometry. Part II. Barometric Hypsometry. By R. S. Wiliamson, Bvt Lieut.-Col. U. S. A., Major Corps of Engineers. With Illustrative Tables and Engravings. Paper No. 15, Professional Papers, Corps of Engineers. 1 vol. 4to, cloth..... 15 00

POOK (S. M.) Method of Comparing the Lines and Draughting Vessels Propelled by Sail or Steam. Including a chapter on Laying off on the Mould-Loft Floor. By Samuel M. Pook, Naval Constructor. 1 vol. 8vo, with illustrations, cloth..... 5 00

ALEXANDER (J. H.) Universal Dictionary of Weights and Measures, Ancient and Modern, reduced to the standards of the United States of America. By J. H. Alexander. New edition, enlarged. 1 vol. 8vo, cloth..... 3 50

WANKLYN. A Practical Treatise on the Examination of Milk, and its Derivatives, Cream, Butter and Cheese. By J. Alfred Wanklyn, M. R. C. S., 12mo cloth..... 1 00

RICHARDS' INDICATOR. A Treatise on the Richards Steam Engine Indicator, with an Appendix by R. W. Bacon, M. E. 18mo, flexible, cloth..... 1 00

PORTER (C. T.) A Treatise on the Richards Steam Engine Indicator, and the Development and Application of Force in the Steam Engine. By Charles T. Porter. Third edition, revised and enlarged. 8vo, illustrated, cloth..... 3 50

POPE Modern Practice of the Electric Telegraph. A Hand Book for Electricians and operators. By Frank L. Pope. Ninth edition, revised and enlarged, and fully illustrated. 8vo, cloth..... $2 00

"There is no other work of this kind in the English language that contains in so small a compass so much practical information in the application of galvanic electricity to telegraphy. It should be in the hands of every one interested in telegraphy, or the use of Batteries for other purposes."

EASSIE (P. B.) Wood and its Uses. A Hand-Book for the use of Contractors, Builders, Architects, Engineers, and Timber Merchants. By P. B. Eassie. Upwards of 250 illustrations. 8vo, cloth..... 1 50

SABINE. History and Progress of the Electric Telegraph, with descriptions of some of the apparatus. By Robert Sabine, C. E. Second edition, with additions, 12mo, cloth..... 1 25

BLAKE. Ceramic Art. A Report on Pottery, Porcelain, Tiles, Terra Cotta and Brick. By W. P. Blake, U. S. Commissioner, Vienna Exhibition, 1873. 8vo, cloth..... 2 00

BENET. Electro-Ballistic Machines, and the Schultz Chronoscope. By Lieut.-Col. S. V. Benet, Captain of Ordnance, U. S. Army. Illustrated, second edition, 4to, cloth..... 3 00

MICHAELIS. The Le Boulenge Chronograph, with three Lithograph folding plates of illustrations. By Brevet Captain O. E. Michaelis, First Lieutenant Ordnance Corps, U. S. Army, 4to, cloth..... 3 00

ENGINEERING FACTS AND FIGURES An Annual Register of Progress in Mechanical Engineering and Construction. for the years 1863, 64, 65, 66, 67, 68. Fully illustrated, 6 vols. 18mo, cloth, $2.50 per vol., each volume sold separately.....

HAMILTON. Useful Information for Railway Men. Compiled by W. G. Hamilton, Engineer. Sixth edition, revised and enlarged, 562 pages Pocket form. Morocco, gilt..... 2 00

STUART (B.) How to Become a Successful Engineer. Being Hints to Youths intending to adopt the Profession. Sixth edition. 12mo, boards..... 50

STUART. The Civil and Military Engineers of America. By Gen. C. B. Stuart. With 9 finely executed portraits of eminent engineers, and illustrated by engravings of some of the most important works constructed in America. 8vo, cloth..... $5 00

STONEY. The Theory of Strains in Girders and similar structures, with observations on the application of Theory to Practice, and Tables of Strength and other properties of Materials. By Bindon B. Stoney, B. A. New and revised edition, enlarged, with numerous engravings on wood, by Oldham. Royal 8vo, 664 pages. Complete in one volume. 8vo, cloth..... 12 50

SHREVE. A Treatise on the Strength of Bridges and Roofs. Comprising the determination of Algebraic formulas for strains in Horizontal, Inclined or Rafter, Triangular, Bowstring, Lenticular and other Trusses, from fixed and moving loads, with practical applications and examples, for the use of Students and Engineers. By Samuel H. Shreve, A. M., Civil Engineer. 87 wood-cut illustrations. 2d edition. 8vo, cloth... 5 00

MERRILL. Iron Truss Bridges for Railroads. The method of calculating strains in Trusses, with a careful comparison of the most prominent Trusses, in reference to economy in combination, etc., etc. By Brevet Col. William E. Merrill, U. S. A., Major Corps of Engineers, with nine lithographed plates of Illustrations. 4to, cloth..... 5 00

WHIPPLE. An Elementary and Practical Treatise on Bridge Building. An enlarged and improved edition of the author's original work. By S. Whipple, C. E., inventor of the Whipple Bridges, &c. Illustrated 8vo, cloth..... 4 00

THE KANSAS CITY BRIDGE. With an account of the Regimen of the Missouri River, and a description of the methods used for Founding in that River. By O. Chanute, Chief Engineer, and George Morrison, Assistant Engineer. Illustrated with five lithographic views and twelve plates of plans. 4to, cloth. 6 00

DUBOIS (A. J.) The New Method of Graphical Statics By A. J. Dubois, C. E., Ph. D. With 60 illustrations. 8vo, cloth..... 2 00

MAC CORD. A Practical Treatise on the Slide Valve by Eccentrics, examining by methods the action of the Eccentric upon the Slide Valve, and explaining the Practical processes of laying out the movements, adapting the valve for its various duties in the steam engine. For the use of Engineers, Draughtsmen, Machinists, and Students of Valve Motions in general. By C. W. Mac Cord, A. M., Professor of Mechanical Drawing, Stevens' Institute of Technology, Hoboken, N. J. Illustrated by 8 full page copper-plates. 4to, cloth..... $3 00

KIRKWOOD. Report on the Filtration of River Waters, for the supply of cities, as practised in Europe, made to the Board of Water Commissioners of the City of St. Louis. By James P. Kirkwood. Illustrated by 30 double plate engravings. 4to, cloth, 15 00

PLATTNER. Manual of Qualitative and Quantitative Analysis with the Blow Pipe. From the last German edition, revised and enlarged. By Prof. Th. Richter, of the Royal Saxon Mining Academy. Translated by Prof. H. B. Cornwall, Assistant in the Columbia School of Mines, New York assisted by John H. Caswell. Illustrated with 87 wood cuts, and one lithographic plate. Third edition, revised, 560 pages, 8vo, cloth..... 7 50

PLYMPTON. The Blow Pipe. A Guide to its Use in the Determination of Salts and Minerals. Compiled from various sources, by George W. Plympton, C. E. A. M., Professor of Physical Science in the Polytechnic Institute, Brooklyn, New York, 12mo, cloth..... 1 50

PYNCHON. Introduction to Chemical Physics, designed for the use of Academies, Colleges and High Schools. Illustrated with numerous engravings, and containing copious experiments with directions for preparing them. By Thomas Ruggles Pynchon, M. A., Professor of Chemistry and the Natural Sciences, Trinity College, Hartford New edition, revised and enlarged. and illustrated by 269 illustrations on wood. Crown, 8vo. cloth..... 3 00

ELIOT AND STORER. A compendious Manual of Qualitative Chemical Analysis. By Charles W. Eliot and Frank H. Storer. Revised with the Co-operation of the authors. By William R. Nichols, Professor of Chemistry in the Massachusetts Institute of Technology Illustrated, 12mo, cloth..... $1 50

RAMMELSBERG. Guide to a course of Quantitative Chemical Analysis, especially of Minerals and Furnace Products. Illustrated by Examples By C. F. Rammelsberg. Translated by J. Towler, M. D. 8vo, cloth..... 2 25

DOUGLASS and PRESCOTT. Qualitative Chemical Analysis. A Guide in the Practical Study of Chemistry, and in the Work of Analysis. By S. H. Douglass and A. B. Prescott, of the University of Michigan. New edition. 8vo. *In press.*

JACOB. On the Designing and Construction of Storage Reservoirs, with Tables and Wood Cuts representing Sections, &c, 18mo, boards..... 50

WATT'S Dictionary of Chemistry. New and Revised edition complete in 6 vols 8vo cloth, $62.00. Supplementary volume sold separately. Price, cloth... 9 00

RANDALL. Quartz Operators Hand-Book. By P. M. Randall. New edition, revised and enlarged, fully illustrated. 12mo, cloth 2 00

SILVERSMITH. A Practical Hand-Book for Miners, Metallurgists, and Assayers, comprising the most recent improvements in the disintegration amalgamation, smelting, and parting of the Precious ores, with a comprehensive Digest of the Mining Laws. Greatly augmented, revised and corrected. By Julius Silversmith. Fourth edition. Profusely illustrated. 12mo, cloth..... 3 00

THE USEFUL METALS AND THEIR ALLOYS. including Mining Ventilation, Mining Jurisprudence, and Metallurgic Chemistry employed in the conversion of Iron, Copper, Tin, Zinc, Antimony and Lead ores, with their applications to the Industrial Arts. By Scoffren, Truan, Clay, Oxland, Fairbairn, and others. Fifth edition, half calf..... 3 75

JOYNSON. The Metals used in construction, Iron, Steel, Bessemer Metal, etc., etc. By F. H. Joynson. Illustrated, 12mo, cloth..... $0 75

VON COTTA. Treatise on Ore Deposits. By Bernhard Von Cotta, Professor of Geology in the Royal School of Mines, Freidberg, Saxony. Translated from the second German edition, by Frederick Prime, Jr., Mining Engineer, and revised by the author, with numerous illustrations. 8vo, cloth..... 4 00

GREENE. Graphical Method for the Analysis of Bridge Trusses, extended to continuous Girders and Draw Spans. By C. E. Greene, A. M., Prof. of Civil Engineering, University of Michigan. Illustrated by 3 folding plates, 8vo, cloth..... 2 00

BELL. Chemical Phenomena of Iron Smelting. An experimental and practical examination of the circumstances which determine the capacity of the Blast Furnace, The Temperature of the air, and the proper condition of the Materials to be operated upon. By I. Lowthian Bell. 8vo, cloth..... 6 00

ROGERS. The Geology of Pennsylvania. A Government survey, with a general view of the Geology of the United States, Essays on the Coal Formation and its Fossils, and a description of the Coal Fields of North America and Great Britain. By Henry Darwin Rogers, late State Geologist of Pennsylvania, Splendidly illustrated with Plates and Engravings in the text. 3 vols., 4to, cloth with Portfolio of Maps. 30 00

BURGH. Modern Marine Engineering, applied to Paddle and Screw Propulsion. Consisting of 36 colored plates, 259 Practical Wood Cut Illustrations, and 403 pages of descriptive matter, the whole being an exposition of the present practice of James Watt & Co., J. & G. Rennie, R. Napier & Sons, and other celebrated firms, by N. P. Burgh, Engineer, thick 4to, vol., cloth, $25.00; half mor..... 30 00

CHURCH. Notes of a Metallurgical Journey in Europe. By J. A. Church, Engineer of Mines, 8vo, cloth..... 2 00

BOURNE. Treatise on the Steam Engine in its various applications to Mines, Mills, Steam Navigation, Railways, and Agriculture, with the theoretical investigations respecting the Motive Power of Heat, and the proper proportions of steam engines. Elaborate tables of the right dimensions of every part, and Practical Instructions for the manufacture and management of every species of Engine in actual use. By John Bourne, being the ninth edition of "A Treatise on the Steam Engine," by the "Artizan Club." Illustrated by 38 plates and 546 wood cuts. 4to, cloth..... $15 00

STUART. The Naval Dry Docks of the United States. By Charles B. Stuart late Engineer-in-Chief of the U. S. Navy. Illustrated with 24 engravings on steel. Fourth edition, cloth..... 6 00

ATKINSON. Practical Treatises on the Gases met with in Coal Mines. 18mo, boards..... 50

FOSTER. Submarine Blasting in Boston Harbor, Massachusetts. Removal of Tower and Corwin Rocks. By J. G. Foster, Lieut.-Col. of Engineers, U. S. Army. Illustrated with seven plates, 4to, cloth..... 3 50

BARNES Submarine Warfare, offensive and defensive, including a discussion of the offensive Torpedo System, its effects upon Iron Clad Ship Systems and influence upon future naval wars. By Lieut.-Commander J. S. Barnes, U. S. N., with twenty lithographic plates and many wood cuts. 8vo, cloth..... 5 00

HOLLEY. A Treatise on Ordnance and Armor, embracing descriptions, discussions, and professional opinions concerning the materials, fabrication, requirements, capabilities, and endurance of European and American Guns, for Naval, Sea Coast, and Iron Clad Warfare, and their Rifling, Projectiles, and Breech-Loading; also, results of experiments against armor, from official records, with an appendix referring to Gun Cotton, Hooped Guns, etc., etc. By Alexander L. Holley, B. P., 948 pages, 493 engravings, and 147 Tables of Results, etc. 8vo, half roan. 10 00

SIMMS. A Treatise on the Principles and Practice of Levelling, showing its application to purposes of Railway Engineering and the Construction of Roads, &c. By Frederick W. Simms, C. E. From the 5th London edition, revised and corrected, with the addition of Mr. Laws's Practical Examples for setting out Railway Curves. Illustrated with three Lithographic plates and numerous wood cuts. 8vo, cloth. $2 50

BURT. Key to the Solar Compass, and Surveyor's Companion; comprising all the rules necessary for use in the field; also description of the Linear Surveys and Public Land System of the United States, Notes on the Barometer. suggestions for an outfit for a survey of four months, etc By W. A. Burt, U. S. Deputy Surveyor. Second edition. Pocket book form, tuck..... 2 50

THE PLANE TABLE. Its uses in Topographical Surveying, from the Papers of the U. S. Coast Survey. Illustrated, 8vo, cloth..... 2 00

"This work gives a description of the Plane Table, employed at the U. S. Coast Survey office, and the manner of using it."

JEFFER'S. Nautical Surveying. By W. N. Jeffers, Captain U. S. Navy. Illustrated with 9 copperplates and 31 wood cut illustrations. 8vo, cloth..... 5 00

CHAUVENET. New method of correcting Lunar Distances, and improved method of Finding the error and rate of a chronometer, by equal altitudes. By W. Chauvenet, LL.D. 8vo, cloth..... 2 00

BRUNNOW. Spherical Astronomy. By F. Brunnow. Ph. Dr. Translated by the author from the second German edition. 8vo, cloth..... 6 50

PEIRCE. System of Analytic Mechanics. By Benjamin Peirce. 4to, cloth..... 10 00

COFFIN. Navigation and Nautical Astronomy. Prepared for the use of the U. S. Naval Academy. By Prof. J. H. C. Coffin. Fifth edition. 52 wood cut illustrations. 12mo, cloth..... 3 50

NOBLE (W. H.) Useful Tables. Compiled by W. H. Noble, M. A., Captain Royal Artillery. Pocket form, cloth..... 50

CLARK. Theoretical Navigation and Nautical Astronomy. By Lieut. Lewis Clark, U. S. N. Illustrated with 41 wood cuts. 8vo, cloth..... $3 00

HASKINS. The Galvanometer and its Uses. A Manual for Electricians and Students. By C. H. Haskins. 12mo, pocket form, morocco. 2 50

MORRIS (E.) Easy Rules for the Measurement of Earthworks, by Means of the Prismoidal Formula. By Ellwood Morris, C. E. 78 illustrations. 8vo, cloth..... 1 50

BECKWITH. Observations on the Materials and Manufacture of Terra-Cotta, Stone Ware, Fire Brick, Porcelain and Encaustic Tiles, with remarks on the products exhibited at the London International Exhibition, 1871. By Arthur Beckwith, C. E. 8vo, paper..... 60

MORFIT. A Practical Treatise on Pure Fertilizers, and the chemical conversion of Rock Guano, Marlstones, Coprolites, and the Crude Phosphates of Lime and Alumina generally, into various valuable products. By Campbell Morfit, M.D., with 28 illustrative plates, 8vo, cloth..... 20 00

BARNARD. The Metric System of Weights and Measures. An address delivered before the convocation of the University of the State of New York, at Albany, August, 1871. By F. A. P. Barnard, LL.D., President of Columbia College, New York. Second edition from the revised edition, printed for the Trustees of Columbia College. Tinted paper, 8vo, cloth 3 00

——— Report on Machinery and Processes on the Industrial Arts and Apparatus of the Exact Sciences. By F. A. P. Barnard, LL.D. Paris Universal Exposition, 1867. Illustrated, 8vo, cloth..... 5 00

ALLAN. Theory of Arches. By Prof. W. Allan, formerly of Washington & Lee University, 18mo, b'rds 50

ALLAN (Prof W.) Strength of Beams under Transverse Loads. By Prof. W. Allan, author of "Theory of Arches." With illustrations. 18mo, boards..... 50

MYER. Manual of Signals, for the use of Signal officers in the Field, and for Military and Naval Students, Military Schools, etc. A new edition enlarged and illustrated. By Brig. General Albert J. Myer, Chief Signal Officer of the army, Colonel of the Signal Corps during the War of the Rebellion. 12mo, 48 plates, full Roan..... $5 00

WILLIAMSON. Practical Tables in Meteorology and Hypsometry, in connection with the use of the Barometer. By Col. R. S. Williamson, U. S. A. 4to, cloth..... 2 50

CLEVENGER. A Treatise on the Method of Government Surveying, as prescribed by the U. S. Congress and Commissioner of the General Land Office, with complete Mathematical, Astronomical and Practical Instructions for the Use of the United States Surveyors in the Field. By S. R. Clevenger, Pocket Book Form, Morocco..... 2 50

PICKERT AND METCALF. The Art of Graining. How Acquired and How Produced, with description of colors, and their application. By Charles Pickert and Abraham Metcalf. Beautifully illustrated with 42 tinted plates of the various woods used in interior finishing. Tinted paper, 4to, cloth..... 10 00

HUNT. Designs for the Gateways of the Southern Entrances to the Central Park. By Richard M. Hunt. With a description of the designs. 4to. cloth..... 5 00

LAZELLE. One Law in Nature. By Capt. H. M. Lazelle, U. S. A. A new Corpuscular Theory, comprehending Unity of Force, Identity of Matter, and its Multiple Atom Constitution, applied to the Physical Affections or Modes of Energy. 12mo, cloth... 1 50

CORFIELD. Water and Water Supply. By W. H Corfield, M. A. M, D., Professor of Hygiene and Public Health at University College, London. 18mo, boards..... 50

BOYNTON. History of West Point, its Military Importance during the American Revolution, and the Origin and History of the U. S. Military Academy. By Bvt. Major C. E. Boynton, A.M., Adjutant of the Military Academy. Second edition, 416 pp. 8vo, printed on tinted paper, beautifully illustrated with 36 maps and fine engravings, chiefly from photographs taken on the spot by the author. Extra cloth..... $3 50

WOOD. West Point Scrap Book, being a collection of Legends, Stories, Songs, etc., of the U. S. Military Academy. By Lieut. O. E. Wood, U. S. A. Illustrated by 69 engravings and a copperplate map. Beautifully printed on tinted paper. 8vo, cloth..... 5 00

WEST POINT LIFE. A Poem read before the Dialectic Society of the United States Military Academy. Illustrated with Pen-and-Ink Sketches. By a Cadet. To which is added the song, "Benny Havens, oh!" oblong 8vo, 21 full page illustrations, cloth..... 2 50

GUIDE TO WEST POINT and the U. S. Military Academy, with maps and engravings, 18mo, blue cloth, flexible..... 1 00

HENRY. Military Record of Civilian Appointments in the United States Army. By Guy V. Henry, Brevet Colonel and Captain First United States Artillery, Late Colonel and Brevet Brigadier General, United States Volunteers. Vol. 1 now ready. Vol. 2 in press. 8vo, per volume, cloth..... 5 00

HAMERSLY. Records of Living Officers of the U. S. Navy and Marine Corps. Compiled from official sources. By Lewis B. Hamersly, late Lieutenant U. S. Marine Corps. Revised edition, 8vo, cloth... 5 00

MOORE. Portrait Gallery of the War. Civil, Military and Naval. A Biographical record, edited by Frank Moore. 60 fine portraits on steel. Royal 8vo, cloth..... 6 00

PRESCOTT. Outlines of Proximate Organic Analysis, for the Identification, Separation, and Quantitative Determination of the more commonly occurring Organic Compounds. By Albert B. Prescott, Professor of Chemistry, University of Michigan, 12mo, cloth... 1 75

PRESCOTT. Chemical Examination of Alcoholic Liquors. A Manual of the Constituents of the Distilled Spirits and Fermented Liquors of Commerce, and their Qualitative and Quantitative Determinations. By Albert B. Prescott, 12mo, cloth..... 1 50

NAQUET. Legal Chemistry. A Guide to the Detection of Poisons, Falsification of Writings, Adulteration of Alimentary and Pharmaceutical Substances; Analysis of Ashes, and examination of Hair, Coins, Arms and Stains, as applied to Chemical Jurisprudence, for the Use of Chemists, Physicians, Lawyers, Pharmacists and Experts Translated with additions, including a list of books and Memoirs on Texicology, etc. from the French of A. Naquet. By J. P. Battershall, Ph. D. with a preface by C. F. Chandler, Ph. D., M. D., L. L. D. 12mo, cloth.... 2 00

McCULLOCH. Elementary Treatise on the Mechanical Theory of Heat, and its application to Air and Steam Engines. By R. S. McCulloch, 8vo, cloth.... 3 50

AXON. The Mechanics Friend; a Collection of Receipts and Practical Suggestions Relating to Aquaria—Bronzing—Cements—Drawing—Dyes— Electricity—Gilding—Glass Working—Glues—Horology—Lacquers—Locomotives—Magnetism—Metal-Working—Modelling—Photography—Pyrotechy—Railways—Solders—Steam Engine—Telegraphy—Taxidermy — Varnishes — Water-Proofing and Miscellaneous Tools,—Instruments, Machines and Processes connected with the Chemical and Mechanics Arts; with numerous diagrams and wood cuts. Edited by William E. A. Axon. Fancy cloth..... 1 50

ERNST. Manual of Practical Military Engineering, Prepared for the use of the Cadets of the U. S. Military Academy, and for Engineer Troops. By Capt. O. H. Ernst, Corps of Engineers, Instructor in Practical Military Engineering, U. S. Military Academy. 192 wood cuts and 3 lithographed plates. 12mo, cloth.. 5 00

BUTLER. Projectiles and Rifled Cannon. A Critical Discussion of the Principal Systems of Rifling and Projectiles, with Practical Suggestions for their Improvement, as embraced in a Report to the Chief of Ordnance, U. S. A. By Capt. John S. Butler, Ordnance Corps, U. S. A. 36 plates, 4to, cloth..... 7 50

BLAKE. Report upon the Precious Metals: Being Statistical Notices of the principal Gold and Silver producing regions of the World, Represented at the Paris Universal Exposition. By William P. Blake, Commissioner from the State of California. 8vo, cloth 2 00

TONER. Dictionary of Elevations and Climatic Register of the United States. Containing in addition to Elevations, the Latitude, Mean, Annual Temperature, and the total Annual Rain fall of many localities; with a brief introduction on the Orographic and Physical Peculiarities of North America. By J. M. Toner, M. D. 8vo, cloth..... 3 75

MOWBRAY. Tri-Nitro Glycerine, as applied in the Hoosac Tunnel, and to Submarine Blasting, Torpedoes, Quarrying, etc. Being the result of six year's observation and practice during the manufacture of five hundred thousand pounds of this explosive Mica, Blasting Powder, Dynamites; with an account of the various Systems of Blasting by Electricity, Priming Compounds, Explosives, etc., etc. By George M. Mowbray, Operative Chemist, with thirteen illustrations, tables and appendix. Third Edition. Rewritten. 8vo. cloth..... 3 00

ROBERTS (Joseph). Hand-Book of Artillery for the Service of the United States (Army and Militia), including the Manual and Mechanical Manœuvres of Heavy Artillery. Tenth edition, revised and greatly enlarged. Pocket form, morocco clasp..... 2 00

HAUPT (Herman). Military Bridges, including Designs for Trestle and Truss Bridges for Military Railroads, adapted especially to the wants of the Service of the United States. Illustrated by 69 engravings. 8vo, cloth..... 6 50

AVELING (S. T.) Carpentry and Joinery. A Useful Manual for the Many. Illustrated. 12mo, cloth.... 1 00

GRIFFITH (J. W.) An Elementary Text-Book of the Microscope. With 12 Colored Plates. 12mo, cloth. 3 00

NAPIER (James). Manual of Electro-Metallurgy, including the Applications of the Art to Manufacturing Purposes. Fifth edition. Illustrated. 12mo, cloth. 3 00

DAVIDSON (E. A.) Practical Manual of House Painting, Graining, Marbling, and Sign Writing. Illustrated. 12mo, cloth 3 00

WILSON (Geo.) Inorganic Chemistry. Revised and enlarged by H. G. Madan, M. A. Illustrated. 12mo, cloth..... 1 75

BURN (Robert Scott). Ornamental Drawing and Architectural Design. 200 illustrations. 8vo, cloth..... 1 00

——— Architectural, Engineering, and Mechanical Drawing-Book. 300 illustrations. 8vo, cloth..... 1 00

——— Illustrated Drawing-Book, for the use Schools, Students, and Artisans. 300 Illustrated Drawings. 8vo, cloth..... 1 00

RANKINE (W. J. MACQUORN). A Manual of Applied Mechanics. Numerous illustrations. Crown 8vo, cloth..... $5 00

"Cannot fail to be adopted as a Text-Book. . . . The whole of the information is so admirably arranged, that there is every facility for reference.—*Mining Journal.*

——— A Manual of Civil Engineering. With numerous Tables and illustrations. Crown 8vo, cloth 6 50

——— A Manual of Machinery and Millwork. With nearly 300 woodcuts. Crown 8vo, cloth..... ..... 5 00

"Professor Rankine's 'Manual of Machinery and Millwork' fully maintains the high reputation which he enjoys as a scientific author; higher praise it is difficult to award to any book. It cannot fail to be a lantern to the feet of every Engineer."—*The Engineer.*

——— A manual of the Steam Engine and other Prime Movers. With Diagram, Tables, and illustrations. Crown 8vo, cloth..... 5 00

——— Useful Rules and Tables for Architects, Builders, Engineers, Surveyors, etc. Crown 8vo, cloth..... 3 50

"Undoubtedly the most useful collection of engineering data hitherto produced."—*Mining Journal.*

"A necessity of the Engineer. . . . Will be useful to any teacher of Mathematics."—*Athenæum.*

——— A Mechanical Text-Book; or introduction to the Study of Mechanics. By Professor Rankine and E. F. Bamber. C. E. Crown 8vo, cloth..... 3 50

"Likely to prove invaluable for furnishing a reliable outline of the subjects treated of."—*Mining Journal.*

THE UNIVERSITY SERIES.

No. 1.—ON THE PHYSICAL BASIS OF LIFE. By Prof. T. H. Huxley, LL. D., F. R. S. With an introduction by a Professor in Yale College. 12mo, pp. 36. Paper cover 25

No. 2.—THE CORELATION OF VITAL AND PHYSICAL FORCES. By Prof. George F. Barker, M. D., of Yale College. 36 pp. Paper covers. 25

No. 3.—AS REGARDS PROTOPLASM, in relation to Prof. Huxley's Physical Basis of life. By J. Hutchinson Stirling, F. R. C. S. 72 pp..... 25

No. 4.—ON THE HYPOTHESIS OF EVOLUTION, Phyical and Metaphysical. By Prof. Edward D. Cope. 12mo, 72 pp. Paper covers..... 25

No. 5.—SCIENTIFIC ADDRESSES:—1. On the Methods and Tendencies of Physical Investigation. 2. On Haze and Dust. 3. On the Scientific Use of the imagination. By Prof. John Tyndall, F. R. S. 12mo, 74 pp. Paper covers..... 25
Flex. cloth 50

No. 6.—NATURAL SELECTION AS APPLIED TO MAN. By Alfred Russell Wallace. This pamphlet treats (1) of the Development of Human Races under the Law of Selection; (2) the limits of Natural Selection as applied to Man. 54 pp..... 25

No. 7.—SPECTRUM ANALYSIS. Three lectures by Profs. Roscoe, Huggins and Lockyer. Finely illustrated. 88 pp. Paper covers..... 25

No. 8.—THE SUN. A sketch of the present state of scientific opinion as regards this body, By Prof. C. A. Young, Ph. D., of Dartmouth College. 58 pp. Paper covers..... 25

No. 9.—THE EARTH A GREAT MAGNET. By A. M. Mayer, Ph. D., of Stevens Institute. 72 pp. Paper covers 25
Flexible cloth 50

No. 10.—MYSTERIES OF THE VOICE AND EAR. By. Prof. O. N. Rood, Columbia College, New York. Beautifully illustrated. 38 pp. Paper covers..... 25

VAN NOSTRAND'S SCIENCE SERIES.

No. 1.—CHIMNEYS FOR FURNACES, FIRE-PLACES, AND STEAM BOILERS. By R. Armstrong, C. E. 18mo, boards..... 50

No. 2.—STEAM BOILER EXPLOSIONS. By Zerah Colburn. 18mo, boards..... 50

No. 3.—PRACTICAL DESIGNING OF RETAINING WALLS. By Arthur Jacob, A. B. 18mo, boards..... 50

No. 4.—PROPORTIONS OF PINS USED IN BRIDGES. By Charles Bender, C. E. 18mo, boards..... 50

No. 5.—VENTILATION OF BUILDINGS. By W. F. Butler. 18mo, boards..... 50

No. 6.—ON THE DESIGNING AND CONSTRUCTION OF STORAGE RESERVOIRS. By Arthur Jacob, A. B. 18mo, boards..... 50

No. 7.—SURCHARGED AND DIFFERENT FORMS OF RETAINING WALLS. By James S. Tate, C. E. 18mo, boards..... 50

No. 8.—A TREATISE ON THE COMPOUND ENGINE. By John Turnbull, Jr. 18mo, boards. 50

No. 9.—FUEL. By C. William Siemens, D. C. L.; to which is appended the VALUE OF ARTIFICIAL FUEL AS COMPARED WITH COAL. By John Wormald, C. E. 18mo, boards.. 50

No. 10.—COMPOUND ENGINES. Translated from the French of A. Mallet. With illustrations. 18mo, boards..... 50

No. 11.—THEORY OF ARCHES. By Prof. W. Allan. 18mo, boards..... 50

No. 12.—A THEORY OF VOUSSOIR ARCHES. By Prof. W. E. Cain. 18mo, boards..... 50

No. 13.—GASES MET WITH IN COAL MINES. By J. J. Atkinson. 18mo, boards 50

No. 14.—FRICTION OF AIR IN MINES. By. J. J. Atkinson. 18mo, boards 50

No. 15.—SKEW ARCHES. By Prof. E. W. Hyde, C. E. Illustrated. 18mo, boards 50

No. 16.—A GRAPHIC METHOD FOR SOLVING CERTAIN ALGEBRAIC EQUATIONS. By Prof. George L. Vose. With illustrations. 18mo, boards..... 50

No. 17.—WATER AND WATER SUPPLY. By Prof. W. H. Corfield, of the University College, London. 18mo, boards 50

No 18.—SEWERAGE AND SEWAGE UTILIZATION. By Prof. W. H. Corfield, M. A., of the University College, London. 18mo, boards..... 50

No. 19.—STRENGTH OF BEAMS UNDER TRANSVERSE LOADS. By Prof. W. Allan, author of "Theory of Arches." With illustrations 18mo, boards 50

No. 20.—BRIDGE AND TUNNEL CENTRES. By John B. McMaster, C. E. With illustrations. 18mo, boards..... 50

No. 21.—SAFETY VALVES. By Richard H. Buel, C. E. With illustrations. 18mo, boards..... 50

No. 22.—HIGH MASONRY DAMS. By John B. McMaster, C. E. With illustrations. 18mo, boards 50

No. 23—THE FATIGUE OF METALS UNDER REPEATED STRAINS. From the German of Ludwig Spangenburg..... 50

VAN NOSTRAND'S

Eclectic Engineering Magazine,

LARGE 8VO, MONTHLY

Terms, $5.00 per annum, in advance.

Single Copies, 50 *Cents*.

First Number was issued January 1, 1869.

VAN NOSTRAND'S MAGAZINE consists of Articles, Original and Selected, as also Matter condensed from all the Engineering Serial Publications of Europe and America.

FOURTEEN VOLUMES NOW COMPLETE.

NOTICE TO NEW SUBSCRIBERS—Persons commencing their subscriptions with the Fifteenth Volume (July, 1876), and who are desirous of possessing the work from its commencement, will be supplied with Volumes I to XIV, inclusive, neatly bound in cloth, for $38 00. Half morocco $59 00. Sent free by mail or express on receipt of price.

NOTICE TO CLUBS.—An extra copy will be supplied, gratis, to every Club of five subscribers, at $5.00 each, sent in one remittance.

This magazine is made up of copious reprints from the leading scientific periodicals of Europe, together with original articles. It is extremely well edited and cannot fail to prove a valuable adjunct in promoting the engineering skill of this country.—*New York World.*

No person intererested in any of the various branches of the engineering profession can afford to be without this magazine.—*Telegrapher.*

The most useful engineering periodical extant, at least for American readers.—*Chemical News.*

As an abstract and condensation of current engineering literature this magazine will be of great value, and as it is the first enterprise of the kind in this country, it ought to have the cordial support of the engineering profession and all interested in mechanical or scientific progress.—*Iron Age.*

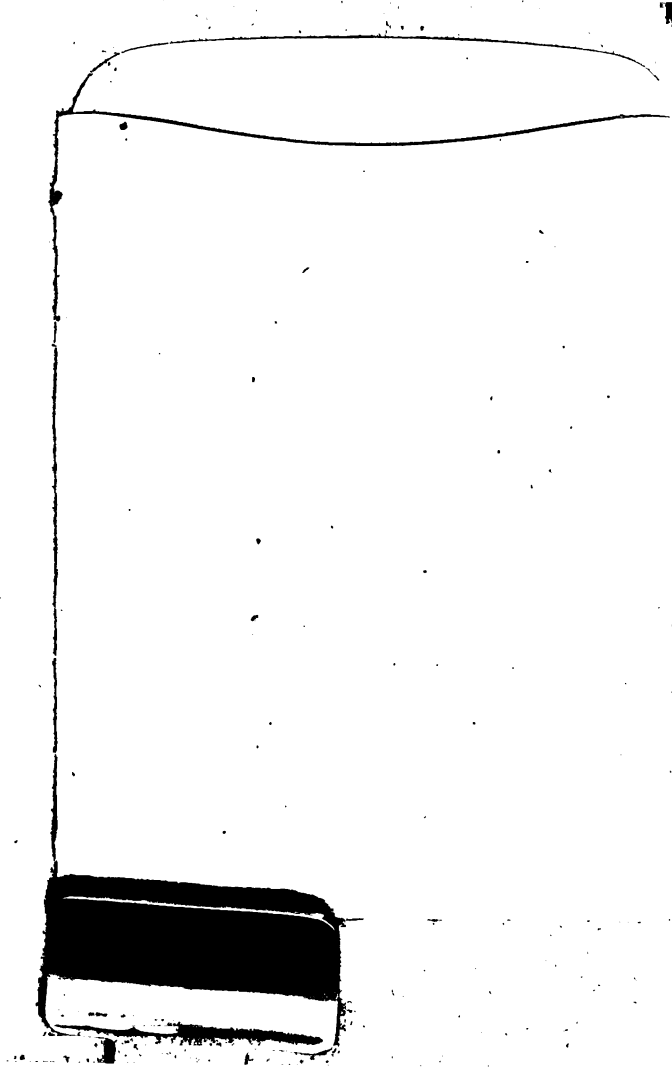
24

THE VAN NOSTRAND SCIENCE SERIES.

No. 44.—TURBINE WHEELS. By Prof. W. P. Trowbridge.
No. 45.—THERMODYNAMICS. By Prof H. T. Eddy.
No. 46.—ICE-MAKING MACHINES. From the French of M. Le Doux.
No. 47.—LINKAGES; the Different Forms and Uses of Articulated Links. By J. D. C. De Roos.
No. 48.—THEORY OF SOLID AND BRACED ARCHES. By Wm. Cain, C. E.
No. 49.—ON THE MOTION OF A SOLID IN A FLUID. By Thomas Craig, Ph. D.
No. 50.—DWELLING HOUSES; their Sanitary Construction and Arrangements. By Prof. Wm. H. Corfield.
No. 51.—THE TELESCOPE: Its Construction, &c. By Thomas Nolan.
No. 52.—IMAGINARY QUANTITIES. Translated from the French of M. Argand. By Prof. Hardy.
No. 53.—INDUCTION COILS: How Made and How Used. 3d Edition.
No. 54.—KINEMATICS OF MACHINERY. By Prof. Kennedy. With an introduction by Prof. Thurston.
No. 55.—SEWER GASES. By A. De Varona.
No. 56.—THE ACTUAL LATERAL PRESSURE OF EARTHWORK. By Benj. Baker, M. Inst. C. E.
No. 57.—INCANDESCENT ELECTRIC LIGHTS, By Compte Th. Du Moncel and Wm. Henry Preece. 2d Edition.
No. 58.—THE VENTILATION OF COAL MINES. By W. Fairley, M. E., F. S. S.
No. 59.—RAILROAD ECONOMICS; or Notes, with Comments. By S. W. Robinson, C. E.
No. 60.—STRENGTH OF WROUGHT IRON BRIDGE MEMBERS. By S. W. Robinson, C. E.
No. 61.—POTABLE WATER, and the Different Methods of Detecting Impurities. By Chas. W. Folkard.
No. 62.—THE THEORY OF THE GAS ENGINE. By Dugald Clerk.
No. 63.—HOUSE DRAINAGE AND SANITARY PLUMBING. By W. P. Gerhard. 2d Edition.
No. 64.—ELECTRO-MAGNETS. By Th. du Moncel.
No. 65.—POCKET LOGARITHMS TO FOUR PLACES OF DECIMALS.
No. 66.—DYNAMO-ELECTRIC MACHINERY. By Silvanus P. Thompson.
No. 67.—HYDRAULIC TABLES. By P. J. Flynn, C. E.
No. 68.—STEAM HEATING. By Robert Briggs.
No. 69.—CHEMICAL PROBLEMS. By Prof. Foye. 3d Ed.
No. 70.—EXPLOSIVE MATERIALS. By M. P. E. Berthelot.
No. 71.—DYNAMIC ELECTRICITY. By John Hopkinson, J. A. Schoolbred and R. E. Day.

8908967427 9

B89089674279A



8908967427 9

b89089674279a